NeuLAND demonstrator at SAMURAI: commissioning and efficiency studies

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NeuLAND (New Large-Area Neutron Detector) is the new neutron detector being developed for the R^{3}B setup (Reactions with Relativistic Radioactive Beams) at FAIR, Germany. This time-of-flight spectrometer is designed to have an invariant-mass resolution of $\Delta E < 20$ keV at 100 keV above the neutron threshold[1)] and identify six coincident neutrons.

This high-granularity detector will consist of 3000 single plastic-scintillator bars organised in 30 modular double-planes, each assembled out of 50 horizontal and 50 vertical scintillator bars of $5 \times 5 \times 250$ cm^3.

In January 2015, the first four double-planes of NeuLAND – the so-called demonstrator – were shipped from GSI in Germany to the RIBF in Japan. By adding NeuLAND to the neutron detection system NEBULA at SAMURAI, the multi-neutron detection efficiency and position resolution of the system are improved significantly. This allows for measurement of 3- and 4-neutron-unbound nuclear systems with good statistics, as conducted in autumn 2015 with the spectroscopy of unbound neutron-rich oxygen isotopes[2)].

During the autumn campaign, the performance of the 400 single NeuLAND modules for fast neutrons at SAMURAI was studied in a one-day machine-study experiment using quasi-monoenergetic neutrons from the ^{7}Li(p,n)^{7}Be reaction. The aim was to extract the one-neutron detection efficiency, study the detector response of NeuLAND and NEBULA at 110 MeV and 250 MeV, and establish a method to separate multi-neutron events with the help of simulations.

In this experiment, NeuLAND was placed 10.87 m downstream from the target at zero degrees. The two NEBULA sub-detectors were located behind it. In front of NeuLAND, a layer of eight 1 cm thin plastic scintillators was placed to veto charged-particle events. The 800 NeuLAND PMT channels were read out with TacQuila electronics developed at GSI, which include QDC, TDC, and trigger multiplexer boards.

To determine the one-neutron detection efficiency of the NeuLAND demonstrator at 110 MeV and 250 MeV, the neutrons from ^{7}Li(p,n)^{7}Be(g. s. + 430 keV) were measured. In this charge-exchange reaction, almost monoenergetic neutrons were produced, as either the ^{7}Be ground state or excited state at 430 keV is directly populated. These neutrons were emitted in the forward direction and detected by NeuLAND, whereas the unreacted protons were bent in the SAMURAI dipole magnet.

The secondary proton beam was produced by the fragmentation of a ^{48}Ca primary beam at 345 MeV/nucleon and impinged on the 1.05 g/cm^2 thick natural Li target. The incident proton-beam rate was about 1 MHz and the reaction trigger rate (NeuLAND×Beam) about 1.5 kHz. The beam spot was determined by two plastic-scintillator veto-counters with a hole diameter of 3 cm.

In order to identify one-neutron events in NeuLAND, the neutron velocity spectrum, shown in Fig. 1, is considered. The peak marked by the fitted curve is associated with the response to quasi-monoenergetic neutrons; the continuum is mainly caused by neutrons from other break-up reactions.
The mean time resolution obtained from cosmic-ray data for horizontal bars is $\sigma_t = 118(18)$ ps with an energy cut $E > 5$ MeVee, a high multiplicity condition, and a horizontal position $|x| < 50$ cm.

The final results from this calibration measurement with high-energy monoenergetic neutrons will allow the precise determination of cross sections in measurements using NeuLAND at SAMURAI.

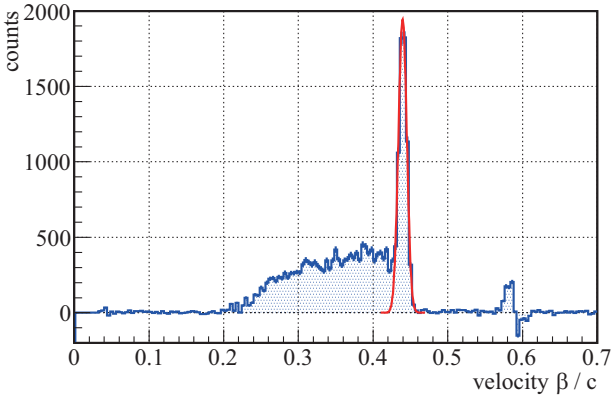

Fig. 1. Preliminary experimental velocity spectrum of NeuLAND for ∼ 110 MeV neutrons with veto condition on charged particles, background subtraction, spatial cut, and an energy cut $E > 5$ MeVee. The background was evaluated with an empty-target run. The integral under the red curve indicates the neutron events.

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