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Nuclear Instruments and Methods in Physics Research A 543 (2005) 517–527
NUCLEAR INSTRUMENTS & METHODS IN PHYSICS RESEARCH Section A
www.elsevier.com/locate/nima

Construction of a modular large-area neutron detector for the NSCL

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Received 22 October 2004; accepted 17 December 2004
Available online 3 February 2005

Abstract

A collaboration of ten institutions, including a large number of undergraduate schools, proposed and constructed a highly efficient large-area neutron detector. The modular neutron array (MoNA) is designed to detect high-energy neutrons in experiments with fast rare isotopes at the National Superconducting Cyclotron Laboratory. It consists of 144 individual detector modules of plastic scintillator, is position sensitive, and features multi-hit capability. The

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doi:10.1016/j.nima.2004.12.020

MoNA project involves undergraduate students from the collaborating colleges and universities and gives them the possibility to take part in research at the forefront of nuclear physics.

PACS: 29.30.Hs; 29.40.Gx; 29.40.Mc

Keywords: Neutron detection; Plastic scintillator array

1. Motivation

The study of nuclei close to the neutron drip-line has greatly expanded in recent years. The increased interest is based on new phenomena that have already been observed or are predicted to occur in these nuclei [1,2]. At the neutron drip-line, the binding energy of a single neutron vanishes, leaving a system that is unbound with respect to prompt neutron emission. The investigation of these neutron-unbound systems can provide important insight into the interaction between nucleon and nucleus far from stability [3]. With the new coupled cyclotron facility at the National Superconducting Cyclotron Laboratory (NSCL) [4], a large number of neutron-rich systems become available to be studied for the first time.

Coincidence experiments between neutrons and charged fragments are an essential tool to study nuclei near the neutron drip-line. An already well-established technique to study neutron-rich systems is to measure the products of a breakup reaction. In order to be able to make a full reconstruction of the nucleus before the breakup, the detection of the neutron (or neutrons) in coincidence with the charged breakup fragment is necessary. Although breakup cross-sections for loosely bound systems are relatively high, the beam intensities for these extreme nuclei are typically low, and a highly efficient detector is needed if one wants to study the correlation of multiple neutrons. Breakup reactions have also been used to form neutron-unbound states; there the effects of the final-state interaction are revealed by measuring the constituents of the unbound state in coincidence.

A new sweeper magnet [5,6] has been constructed and is designed to deflect charged reaction products of the rare-isotope beams delivered by the coupled cyclotron facility, so that neutrons can be detected at around 0° scattering angle. The existing neutron walls [7] were recognized as a limiting factor in coincidence experiments at the upgraded NSCL facility because they are optimized for neutron energies below 50 MeV, and have low detection efficiency at higher energies. In order to make full use of the capabilities of the new beam analysis system [8] and the sweeper magnet, a large-area neutron detector with high detection efficiency is essential.

With all this in mind, our group proposed and built a highly efficient large-area neutron detector for use at the NSCL [9,10]. In its standard configuration, the modular neutron array (MoNA) has an active area of $2.0\,\mathrm{m} \times 1.6\,\mathrm{m}$. It measures both the position and time of neutron events with multiple-hit capability. Its detection efficiency was maximized for the high-beam velocities that are available with the coupled cyclotron facility. For neutrons ranging from 50 to 250 MeV in energy, it is designed to have an efficiency of up to 70% and expands the possible coincidence experiments with neutrons to measurements which were previously not feasible.

The detector is used in combination with the new sweeper magnet and its focal plane detectors for charged particles. In addition, MoNA is designed in such a way that it can be transported between experimental vaults and thus be used in combination with the sweeper magnet installed at the S800 magnet spectrograph [11]. Finally, due to its high-energy detection efficiency, this detector will be well-suited for experiments with fast fragmentation beams at the proposed Rare Isotope Accelerator [12].