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Opportunities for Undergraduate Research in Nuclear Physics

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Abstract

University of Dallas (UD) physics majors are offered a variety of undergraduate research opportunities in nuclear physics through an established program at the University of Kentucky Accelerator Laboratory (UKAL). The 7-MV Model CN Van de Graaff accelerator and the neutron production and detection facilities located there are used by UD students to investigate how neutrons scatter from materials that are important in nuclear energy production and for our basic understanding of how neutrons interact with matter. Recent student projects include modeling of the laboratory using the neutron transport code MCNP to investigate the effectiveness of laboratory shielding, testing the long-term gain stability of C_6D_6 liquid scintillation detectors, and deducing neutron elastic and inelastic scattering cross sections for ^{12}C. Results of these student projects are presented that indicate the pit below the scattering area reduces background by as much as 30%; the detectors show no significant gain instabilities; and new insights into existing ^{12}C neutron inelastic scattering cross-section discrepancies near a neutron energy of 6.0 MeV are obtained.

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Keywords: Undergraduate research; MCNP calculations; neutron cross sections.

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1. Introduction

The University of Dallas (UD), through a collaborative program with the University of Kentucky and the United States Naval Academy (USNA), has offered undergraduate students the ability to conduct experimental nuclear physics research at the University of Kentucky Accelerator Laboratory (UKAL) for almost three decades. UKAL offers students the hands-on nuclear physics experience that many undergraduates seek as they discern their graduate school and career objectives. Several students who have participated in the research program in the last few years have gone on to graduate school in nuclear physics, nuclear engineering, and radiation medicine. Furthermore, the Bachelor of Science degree at UD requires that undergraduates complete an intensive research project, write a thesis, and give a presentation over their work at a professional conference. During most years two to five UD undergraduate student's complete nuclear physics projects at UKAL; the advantages of a university research laboratory and the variety of projects available at such a facility are immeasurable.

The projects completed most recently by UD students are part of an experimental program to measure high-precision absolute differential cross sections in both the neutron and γ-ray exit channels following neutron scattering reactions. The cross sections studied at UKAL are those considered most critical for the nuclear physics and engineering communities and are used by data evaluators trying to develop a global understanding of how neutrons interact with matter. The focus during the last few years has been neutron scattering cross section measurements on ^{23}Na (Vanhoy, 2015), ^{54,56}Fe, and ^{12}C, which are important in structural materials and coolants in reactor environments. During the last two years, student projects have been modeling the facilities at UKAL using the Monte Carlo N-Particle (MCNP) code (Los Alamos, 2016 and Goorley, 2014) to investigate the effectiveness of the pit under the neutron hall in reducing neutron-induced background; the measurement and analysis of neutron elastic and inelastic scattering differential cross sections from ^{12}C to investigate the nearly 40% discrepancies observed in existing values; and a study of the stability of the deuterated benzene (C_6D_6) scintillation detectors over extended experimental measurements.

2. Facilities

2.1. UKAL Accelerator and Neutron Production and Detection Facilities

The accelerator used for all experimental measurements at UKAL is a model CN 7 MV Van de Graaff that was installed in 1963 and has been used almost continuously for neutron scattering measurements, nuclear structure studies of stable nuclei, nuclear astrophysics, and applied physics research. The accelerator and facility are shown in Fig. 1. Beams of ^{1}H, ^{2}H, ^{3}He and ^{4}He ions are available at the facility in either DC or pulsed-beam mode. Beams are

Figure 1. Three views of the UKAL accelerator facility: (left) the silo in which the accelerator is housed on the University of Kentucky campus; (middle) the accelerator with tank on; and (right) the accelerator with the tank removed and the resistor column and terminal visible.