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Undergraduate Measurements of Neutron Cross Sections

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Abstract

Undergraduate students at the University of Dallas have investigated basic properties of nuclei through γ-ray and neutron spectroscopy following neutron scattering. The former has been used primarily for nuclear structure investigations, while the latter has been used to measure neutron scattering cross sections important for fission reactor applications. A series of (n,n') and $(n,n'\gamma)$ measurements have been made on ^{54}Fe and ^{56}Fe to determine neutron cross sections for scattering to excited levels in these nuclei. The former provides the cross sections directly and the latter are used to deduce inelastic neutron scattering cross sections by measuring the γ-ray production cross sections to states not easily resolved in neutron spectroscopy. All measurements have been completed at the University of Kentucky Accelerator Laboratory using a 7-MV Model CN Van de Graaff accelerator, along with the neutron production and neutron and γ-ray detection systems located there. Students participate in accelerator operation, experimental setup, data acquisition, and data analyses. An overview of the research program and student contributions is presented.

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Keywords: Undergraduate research; γ-ray spectroscopy; neutron elastic and inelastic scattering; differential scattering cross sections.

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1. Introduction

Science majors at the University of Dallas (UD) participate in undergraduate research to help fulfill part of the requirement for the Bachelor of Science (BS) degree. For physics and chemistry majors, one of the areas of study available for their research is experimental nuclear physics, particularly in the subareas of nuclear structure and neutron scattering. For the last several years UD students have participated in a series of (n,n), (n,n') and $(n,n'\gamma)$ studies to measure neutron scattering cross sections from materials that are important for the design of next-generation nuclear fission reactors (see DOE [1]) and also for data evaluation purposes as global models describing neutron scattering data are developed (see Aliberti *et al.*[2,3,4]). The purpose of these studies is to measure elastic and inelastic neutron scattering cross sections for ^{54,56}Fe, since iron is such an important structural material in the design of nuclear fission reactors, and for ^{23}Na, which is the coolant in the sodium-cooled fast reactor. The cross sections obtained from these measurements are important not only for reactor design considerations but also for comparison to existing global model calculations of neutron scattering cross sections available at online data bases, such as the Evaluated Nuclear Data File (ENDF) maintained at the National Nuclear Data Center at Brookhaven National Laboratory (see Chadwick [5]). All the measurements are conducted away from the UD campus at the University of Kentucky Accelerator Laboratory (UKAL).

The 7 MV modified Model CN Van de Graaff accelerator located at UKAL has been used almost continuously for graduate and undergraduate student education since 1963 as part of a larger nuclear science research program that includes investigations of important questions in nuclear structure, nuclear astrophysics, neutron scattering, and applied nuclear science. UKAL is considered a university-based laboratory, but because of its ability to produce nearly mono-energetic fluences of neutrons for scattering and reaction studies, the laboratory has become in many respects a user facility. Students and faculty from UD, the United States Naval Academy (USNA), and UK have worked collaboratively for many years in both nuclear structure and neutron scattering studies. Over thirty UD students have completed their undergraduate research at UKAL - a facility that is very amenable to teaching undergraduates since they can participate in all components of the experiment from accelerator operation and repair, detector and electronic setup and operation, and data acquisition and analysis.

2. Experimental Apparatus

2.1. University of Dallas Facilities for Nuclear Physics

The UD nuclear physics experimental facilities have no in-house neutron production capabilities. Students do have available NaI scintillation detectors and electronic equipment for singles and coincidence spectroscopy. Most of this equipment became available with a generous donation by UD alumnus Ed Stanley. This equipment is shown in Fig. 1 being used by 2015 senior Laura Aumen. The experimental research completed for undergraduate theses is performed at UKAL because of the limited nature of in-house facilities at UD.

Figure 1. Nuclear spectroscopy equipment at the University of Dallas.