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Physics Procedia 90 (2017) 440 – 447

Physics Procedia

Conference on the Application of Accelerators in Research and Industry, CAARI 2016, 30 October – 4 November 2016, Ft. Worth, TX, USA

Research at the University of Kentucky Accelerator Laboratory

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Abstract

The Department of Physics and Astronomy at the University of Kentucky operates a 7-MV CN Van de Graaff accelerator that produces primary beams of protons, deuterons, and helium ions. An in-terminal pulsing and bunching system operates at 1.875 MHz and is capable of providing 1 ns beam bunches at an average current of several microamperes. Nearly all ongoing research programs involve secondary pulsed neutrons produced with gas cells containing deuterium or tritium, as well as with a variety of solid targets. Most experiments are performed at a target station positioned over a deep pit, so as to reduce the background created by backscattered neutrons. Recent experiments will be described; these include: measurements of *n-p* scattering total cross sections from E_n = 90 to 1800 keV to determine the *n-p* effective range parameter; the response of the plastic scintillator BC-418 below 1 MeV to low-energy recoil protons; *n-p* radiative capture cross sections important for our understanding of nucleosynthesis approximately 2 minutes after the occurrence of the Big Bang; γ-ray spectroscopy following inelastic neutron scattering to study nuclear structure relevant to double-β decay and to understand the role of phonon-coupled excitations in weakly deformed nuclei; and measurements of neutron elastic and inelastic scattering cross sections for nuclei that are important for energy production and for our global understanding of the interaction of neutrons with matter.

Peer-review under responsibility of the Scientific Committee of the Conference on the Application of Accelerators in Research and Industry

Keywords: Neutron-proton total cross sections; $p(n,d\gamma)$ radiative capture cross sections; neutron production; neutron detection; γ-ray spectroscopy; neutron elastic scattering cross sections; neutron inelastic scattering cross sections

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Peer-review under responsibility of the Scientific Committee of the Conference on the Application of Accelerators in Research and Industry
doi:10.1016/j.phpro.2017.09.048

1. Introduction

The 7 MV modified Model CN Van de Graaff accelerator located at the University of Kentucky Accelerator Laboratory (UKAL) has been used extensively since its installation by High Voltage Engineering in 1963 for the investigation of important questions in nuclear astrophysics, nuclear structure, neutron scattering, and applied nuclear science. The laboratory is a founding member of the Association for Research at University Nuclear Accelerators (ARUNA) and has long been used to provide graduate and undergraduate students the facilities for their initiation into nuclear science, as well as for postdoctoral scholars to gain experience with neutron-induced reactions and scattering. UKAL is also used for the testing and development of novel neutron detectors and particle-detection techniques.

Recent investigations at UKAL have focused on the measurements of neutron-proton (*n-p*) scattering and radiative capture cross sections below 2 MeV where existing measurements are not only sparse, but inconsistencies exist between different measurements and with existing model calculations, and because of their importance to our understanding of the nucleon-nucleon interaction and in models of Big Bang nucleosynthesis (Daub (2012)). Other areas of experimental emphasis at UKAL include nuclear structure studies of collective modes of excitation in nuclei, which take advantage of using fast neutrons to study low-spin, non-yrast states through γ-ray spectroscopy following inelastic neutron scattering, and measurements of neutron elastic and inelastic scattering cross sections on materials important for fission reactor applications and our global understanding of how neutrons interact with matter. These research programs are conducted in collaboration with researchers from MIT (e.g., Daub et al., (2013)), LANL (e.g., Henzl et al., (2010)), the United States Naval Academy (e.g., Vanhoy et al., (2015)), the University of Dallas (e.g., Hicks et al., (2017)), Georgia Institute of Technology (e.g., Peters et al., (2016)), and the University of Guelph (e.g., Bildstein et al., (2013)), as well as with other institutions. Neutron detection innovations that have recently taken advantage of the UKAL neutron production facilities include measurements of the response of BC-418 plastic scintillator by detecting low-energy neutrons scattered by an active scintillator target. The UKAL facilities and overview of some current research efforts are given below.

2. Experimental Apparatus

2.1. The UKAL accelerator

The accelerator at UKAL operates with a tank gas of N_2:CO_2 in a 4:1 admixture, and it is capable of producing DC or pulsed beams of ^{1}H, ^{2}H, ^{3}He, and ^{4}He ions with a maximum energy of 7 MeV. Beams are pulsed at a frequency of 1.875 MHz and can be bunched such that each pulse has a FWHM of ~1 ns. While much of the accelerator, as shown in Fig. 1 (a), and the control panel, as seen in Fig. 1 (b), are from the original installation, upgrades were completed in 1988 and 1991 that include a new stainless steel accelerator tube, post-acceleration electrostatic focusing capabilities, and an in-terminal buncher from National Electrostatics Corporation.

(a) (b)

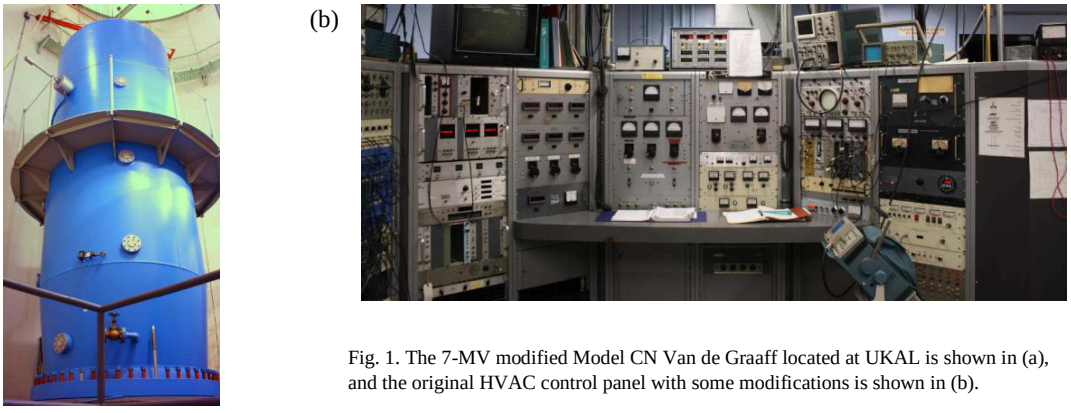

Fig. 1. The 7-MV modified Model CN Van de Graaff located at UKAL is shown in (a), and the original HVAC control panel with some modifications is shown in (b).