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The 88-Inch Cyclotron: A One-Stop Facility for Electronics Radiation and Detector Testing

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The 88-Inch Cyclotron: A One-Stop Facility for Electronics Radiation and Detector Testing

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Abstract— **In outer space down to the altitudes routinely flown by larger aircrafts, radiation can pose serious issues for microelectronics circuits. The 88-Inch Cyclotron at Lawrence Berkeley National Laboratory is a sector-focused cyclotron and home of the Berkeley Accelerator Space Effects Facility, where the effects of energetic particles on sensitive microelectronics are studied with the goal of designing electronic systems for the space community. This paper describes the flexibility of the facility and its capabilities for testing the bombardment of electronics by heavy ions, light ions, and neutrons. Experimental capabilities for the generation of neutron beams from deuteron breakups and radiation testing of carbon nanotube field effect transistor will be discussed.**

Keywords—Radiation Hardening; Single Event Effects; Ion Beam; Neutron Beam; Cyclotron; ECR

I. Introduction

The atmosphere and the Earth's magnetic field shield the planet's surface from most of the ionizing radiation that originates from the Sun and other stars.

The solar wind boils continuously off the Sun and is constituted of 80% protons, 18% alpha particles, and traces of heavier charged particles [1]. It has a similar composition to the galactic cosmic rays that originate outside the solar system. Occasionally, however, a magnetic disturbance in the Sun results in an explosive ejection of huge amounts of matter from the solar corona, known as coronal mass ejection, which can be responsible for showers of high energy particles impacting Earth's atmosphere within 15-20 minutes of the event [2].

The first spacecrafts lost due to total radiation dose effects occurred unexpectedly in 1962. Telstar and six other satellites were lost within a seven-month period after a high altitude nuclear weapon test produced a large number of beta particles, which caused a new and very intense radiation belt lasting until the early 1970s [3].

When high-energy ions enter a material, they lose energy to the medium. The energy loss from the projectile per unit path length is known as stopping power, which has nuclear and electronic components.

The nuclear stopping power is caused by elastic collisions with the nuclei of the target material. The electronic stopping power is produced by inelastic collisions with the electrons [4]. Electronic stopping power is equivalent to the linear energy transfer (LET) for the ions produced by the cyclotron.

The energy deposited from the electronic stopping power produces a dense track of electron-hole pairs along the ion track by the ionization process. If the ion interacts with an electronic semiconductor component, some charge will be collected at the p-n junction, while others will recombine [5]. As a result, a very short duration current pulse is generated at the circuit node, which can produce transient effects such as single-event upset and multiple-bit upset, catastrophic events with single-event latch-up and snapback, and single-event hard errors [6]. Long term material degradation may be produced by rapid charge collection, annealing, or by displacement damage caused by elastic collisions with lattice nuclei.

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