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Evaluation of spectrum and fluxes of the ChipIr facility for atmospheric neutron testing of electronics

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The ChipIr beamline at the Rutherford Appleton Laboratory, UK, is a facility dedicated to fast neutron testing, particularly aimed at evaluating single-event effects (SEEs) on microelectronics. SEEs, induced by energetic particles such as high-energy atmospheric neutrons, pose significant reliability threats to electronic devices utilized in safety-critical applications including avionics, automotive, aerospace, and medical applications. With advancements in microelectronic miniaturization and complexity, rigorous SEE testing has become increasingly critical, demanding precise neutron environments that accurately reflect atmospheric energy distribution. ChipIr extracts fast neutrons from an 800 MeV proton beam impinging on a tungsten target. This specialized setup includes filters and collimators enabling flexible configuration options for researchers. To comprehensively characterize ChipIr's neutron beam, two principal measurement techniques have been employed: activation foil with threshold reactions and silicon diode detectors. Activation foils, composed of diverse materials including gold, bismuth, and cobalt, serve as a passive method enabling determination of neutron flux across a broad energy spectrum. (n,xn) reactions are identified as an important tool for high-energy neutron measurements. Post-irradiation, gamma-rayspectroscopy with high-purity germanium detectors quantifies the activation rates, from which neutron flux spectra are derived through Bayesian unfolding methods. Results indicate that the ChipIr neutron spectrum, spanning from thermal energies up to 800 MeV, mimics the terrestrial atmospheric neutron spectrum, with a flux (E > 10 MeV) of 5.9E6 s-1 cm-2.
Active measurement approaches utilize silicon detectors, enabling real-time monitoring and mapping of beam profiles. Such detectors are sensitive to neutrons with energies greater than 10 MeV, aligning with the established standards for SEE evaluation. Extensive spatial profiling across multiple beam configurations has demonstrated excellent beam uniformity for smaller beam apertures, essential for precise device-level testing, and a defined gradient suitable for larger system-level evaluations. Furthermore, the facility provides a flux reduction capability via steel and polyethylene attenuators, maintaining spectral integrity sufficiently close to atmospheric conditions, albeit with slight hardening of the neutron spectrum.
The results detailed in this characterization highlight ChipIr's suitability for industry and academic users needing to test the susceptibility of electronics to SEEs in a field that replicate terrestrial conditions.

Authors: CAZZANIGA, Carlo (UKRI-STFC); FROST, Christopher; KASTRIOTOU, Maria; BHUIYAN, Nahid; LILLEY, Steven

Presenter: CAZZANIGA, Carlo (UKRI-STFC)

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