BALLROOM B, C

8:10 AM **OPENING REMARKS**
Thomas Turflinger, Aerospace Corporation, General Chairman

8:15 AM **AWARDS PRESENTATION**
Robert Reed, Vanderbilt University, Radiation Effects Steering Group, Executive Chair

9:05 AM **TECHNICAL SESSION OPENING REMARKS**
Pascale Gouker, MIT Lincoln Laboratory, Technical Program Chair

SESSION A **SINGLE EVENT EFFECTS: MECHANISMS AND MODELING**

9:10 AM SESSION INTRODUCTION
Chair: Joel Hales, U.S. Naval Research Laboratory

A-1 **Single Event Effects in 3D NAND Flash Memory Cells with Replacement**
9:15 AM **Gate Technology**

M. Bagatin[1], S. Gerardin[1], A. Paccagnella[1], A. Costantino[2], V. Ferlet-Cavrois[2], A. Pesce[2], S. Beltrami[3]

1. University of Padova, Italy
2. ESA, Netherlands
3. Micron Technology, Italy

We studied the heavy-ion single event effect response of 3D NAND Flash memory cells with replacement gate technology. Threshold voltage shifts and underlying mechanisms are discussed and compared with previous generation cells with floating-gate architecture.

A-2 **Proton Direct Ionization Upsets at Tens of MeV**
9:30 AM

A. Coronetti[1,2], R. Garcia[1], D. Lucsanyi[1], J. Wang[3], F. Saigné[2], A. Javanainen[4,5], P. Leroux[3]

1. CERN, Switzerland
2. University of Montpellier, France
3. KU Leuven, Belgium
4. University of Jyväskylä, Finland
5. Vanderbilt University, USA

Experimental measurements show an unusually high proton upset cross-section at few tens of MeV for a low core-voltage SRAM. G4SEE simulations confirm that this mechanism is due to proton direct ionization.

A-3 **Leveraging the Wavelength Dependence of Optical Charge Generation**
9:45 AM **to Correlate Ion- and Laser-Induced Transients in Modern SiGe HBTs**

A. Idelfonso[1], J. M. Hales[1,2], A. Khachatrian[1], P. D. Cunningham[1], D. Nergui[3], G. N. Tzintzarov[3], A. P. Omprakash[4], J. D. Cressler[3], D. McMorrow[1]

1. U.S. Naval Research Laboratory, USA
2. Jacobs, Inc., USA
3. Georgia Institute of Technology, USA
4. Raytheon, USA

Single-event transients were measured in SiGe HBTs using carrier injection via two-photon absorption (TPA) at different wavelengths. Experiments and simulations indicate that the choice of wavelength has important implications for ion/laser correlation when using TPA.

POSTER PAPERS

PA-1 Influence of Radiation Environment Variability on Cumulative Heavy-Ion-Induced Leakage Current in SiC Power Devices

R. A. Johnson[1,2], A. F. Witulski[1], K. F. Galloway[1], B. D. Sierawski[1], A. L. Sternberg[1], M. L. Alles[1], D. R. Ball[1], R. A. Reed[1], R. D. Schrimpf[1], J. M. Hutson[1,3], J.-M. Lauenstein[4]

1. Vanderbilt University, USA

2. Ball Aerospace, USA

3. Lipscomb University, USA

4. NASA GSFC, USA

Previously reported methods for characterizing SELC in SiC devices are used to translate environmental fluence spectra into cumulative leakage current increases. Shielding thickness and operating voltage are shown to influence the cumulative leakage current increase.

PA-2 Effect of Biased Field Rings to Improve Charge Removal After Heavy Ion Strikes in Vertical Geometry β-Ga_2O_3 Rectifiers.

R. Sharma[1,2], M. E. Law[1], F. Ren[1], S. J. Pearton[1]

1. University of Florida, USA

2. Infineon, USA

The response to a heavy-ion strike and the resulting single effect burnout on beta-Ga_2O_3 Schottky diodes with biased field rings is investigated via TCAD. The charge removal after simulated heavy-ion strikes is greatly improved.

PA-3 Examination of Trapping Effects on Single Event Transients in GaN HEMTs

T. Nelson[1], D. G. Georgiev[1], M. R. Hontz[2], R. Khanna[1], A. Ildefonso[3], A. D. Koehler[3], A. Khachatrian[3], D. McMorrow[3]

1. University of Toledo, USA

2. Naval Surface Warfare Center, Philadelphia Division, USA

3. U.S. Naval Research Laboratory, USA

The role of threading dislocations on single event radiation effects in GaN HEMTs is examined. Threading dislocations are introduced into a calibrated TCAD model via cylindrically symmetric trap profiles and compared against pulsed laser data.

PA-4 Using Track Structure Theory to Calculate Proton Cross-Sections from Heavy-Ion Data

D. L. Hansen[1], B. Vermeire[1]

1. Space Micro, USA

This paper uses track structure theory for the calculation of proton SEU cross-sections from heavy-ion data. Evaluating the model using data in the published literature gives a good agreement between calculated and measured values.

PA-5 **Mechanisms of Heavy Ion-, Focused X-Ray-, and Pulsed Laser-Induced Single Event Transients in an Epitaxial Silicon Diode**

K. L. Ryder[1,2], L. D. Ryder[1,2], A. L. Sternberg[2], J. A. Kozub[2], E. X. Zhang[2], S. D. Lalumondiere[3], D. M. Monahan[3], J. P. Bonsall[3], A. Khachatrian[4], S. Buchner[4], D. McMorrow[4], J. M. Hales[4], Y. Zhao[5], L. Wang[5], C. Wang[5], R. A. Weller[2], R. D. Schrimpf[2], S. M. Weiss[2], R. A. Reed[2]

1. NASA Goddard Space Flight Center, USA
2. Vanderbilt University, USA
3. Aerospace Corporation, USA
4. U.S. Naval Research Laboratory, USA
5. Beijing Microelectronics Technology Institute, China

Mechanisms of heavy ion, focused X-ray, and pulsed laser SET experiments are identified, confirming the role of potential modulation. Differences in charge generation distributions are responsible for observed differences in device response.

10:00 AM – 10:30 AM
EXHIBIT HALL A-B-C
BREAK

SESSION B **SINGLE EVENT EFFECTS: DEVICES AND INTEGRATED CIRCUITS**

10:30 AM SESSION INTRODUCTION

Chair: Jeffrey Black, Sandia National Laboratories

B-1 10:35 AM **Radiation-Induced Faults Propagation in Quantum Bits and Quantum Circuits**

D. Oliveira[1], E. Auden[2], P. Rech[3]

1. Federal University of Paraná, Brazil
2. Los Alamos National Laboratory, USA
3. University of Trento, Italy

Through GEANT4 simulations and circuit-level fault-injection we investigate neutron-induced faults generation and propagation in quantum circuits. We discuss the fault model for quantum bits and how to measure the faults impact in the circuit output.

B-2 10:50 AM **Towards Predicting Single-Event Transients in an Operational Amplifier Using a Quasi-Bessel Beam Pulsed-Laser Approach**

J. Hales[1], A. Ildefonso[1], A. Khachatrian[1], S. Buchner[1], D. McMorrow[1]

1. U.S. Naval Research Laboratory, USA

The prediction of heavy-ion-generated single-event transients in an operational amplifier is explored using a quasi-Bessel beam pulsed-laser approach. By tuning to the appropriate laser-equivalent LET, the complicated transient response is accurately reproduced.

B-3 11:05 AM
Low-Energy Ion-Induced Single-Event Burnout in Gallium Oxide Schottky Diodes

R. Cadena[1], D. R. Ball[1], R. D. Schrimpf[1], D. M. Fleetwood[1], R. A. Reed[1], M. L. Alles[1], M. W. McCurdy[1], S. T. Pantelides[1], K. F. Galloway[1], A. F. Witulski[1], E. Farzana[2], J. Speck[2]

1. Vanderbilt University, USA

2. University of California Santa Barbara, USA

Low-energy ion-induced single-event burnout is experimentally observed in β-Ga_2O_3 Schottky diodes at 10% of device lectrical breakdown voltage. TCAD simulations suggest that the SEB is due to ion-induced impact ionization.

B-4 11:20 AM
Characterizing Deep Neural Networks Neutrons-Induced Error Model

F. Fernandes dos Santos[1], A. Kritikakou[1], O. Sentieys[1], P. Rech[2]

1. INRIA, France

2. University of Trento, Italy

We characterize the fault models for Deep Neural Networks (DNNs) in GPUs exposed to neutrons. We observe tolerable and critical errors and show that ECC is not effective in reducing critical errors.

B-5 11:35 AM
Scaling Trends for Single-Event Cross-Section for Conventional D-FF at Bulk FinFET Technology Nodes

Y. Xiong[1], N. Pieper[1], A. Feeley[1], B. Narasimham[2], D. Ball[1], B. Bhuva[1]

1. Vanderbilt University, USA

2. Broadcom, USA

Single event cross-section scaling trends for bulk FinFET nodes are experimentally investigated for D-FF designs with different threshold-voltage options. Results for operating voltage and particle LET show a trend reversal at the 5-nm node.

POSTER PAPERS

PB-1
SEEs Analysis of Placement Solutions for Multi-Core Accelerators on Xilinx UltraScale+ Under Proton Irradiation Test

A. Portaluri[1], S. Azimi[1], C. De Sio[1], D. Rizzieri[1], E. Vacca[1], L. Sterpone[1], D. Merodio Codinachs[2], C. Poivey[2]

1. Politecnico di Torino, Italy

2. European Space Agency, Netherlands

We performed a high-energy proton radiation campaign in order to analyze how different placement layouts of multiple accelerator processing cores can affect the single-event-effect sensitivity of radiation-induced errors on Xilinx Ultrascale+ SRAM-based FPGAs.

PB-2
Single-Event Upset and Transient Response in 22-nm Fully Depleted Silicon-on-Insulator Logic

J. D'Amico IV[1], S. Vibbert[1], A. Watkins[1], B. Fahrenkrug[1], T. Haeffner[1], D. Ball[1], A. Sternberg[1], J. Kauppila[1], L. Massengill[1]

1. Vanderbilt University, USA

Single-event upset and single-event transient responses of logic in a planar 22-nm fully depleted SOI technology are presented alongside several parameters affecting this response. Results indicate relatively small single-event cross sections compared to other technologies.

PB-3 **Impact of Low Energy, Low-Range Ions on Failure Rate Considerations in SiC Power Diodes**

A. Sengupta[1], D. Ball[1], A. Witulski[1], R. Schrimpf[1], K. Galloway[1], R. Reed[1], M. Alles[1], M. McCurdy[1], A. Sternberg[1], R. Johnson[2], M. Howell[1]

1. Vanderbilt University, USA

2. Ball Aerospace, USA

Experimental and simulated heavy-ion responses of SiC power diodes are presented. Results indicate that ions having range less than the epitaxial thickness do not cause degradation or catastrophic failure even above the rated breakdown voltage.

PB-4 **SRAM Multi-Cell Upset Vulnerability at the 5-nm FinFET Node**

N. Pieper[1], Y. Xiong[1], A. Feeley[1], J. Pasternak[2], D. Ball[1], B. Bhuva[1]

1. Vanderbilt University, USA

2. Synopsis, USA

Single-event multi-cell upsets for single-port and two-port SRAM designs as a function of supply voltage for different radiation beams are characterized at the 5-nm bulk FinFET node.

PB-5 **Depth-Dependent Single-Event-Effect Analysis of a COTS 3D-Integrated Imager**

M. Hu[1], F. Padgett III[1], M. McCurdy[1], R. Schrimpf[1], R. Reed[1], M. Alles[1]

1. Vanderbilt University, USA

The area of observed pixels impacted by single alpha particles in a heterogeneously integrated COTS 3D-IC imager is determined by onboard image processing. Spatial profiling reveals SEL in peripheral circuitry of the sandwiched DRAM layer.

PB-6L **The Impact of Inductor Sensitivity and Single-Event Frequency Transients in LC-tank Oscillators**

J. Prinzie[1], G. Adom-bamfi[1], S. Biereigel[2]

1. KU Leuven, Belgium

2. CERN, Switzerland

This paper presents a novel radiation effect in on-chip inductors. Experimental results from irradiation with heavy-ions and protons are shown. A discussion is made on the impact of the PLL bandwidth and system level implications.

11:50 AM - 1:00 PM LUNCH
EXHIBITS ARE OPEN IN HALLS A-B-C

SESSION C **SPACE AND TERRESTRIAL ENVIRONMENTS**
1:00 PM SESSION INTRODUCTION
Chair: Gregory Ginet, MIT Lincoln Laboratory

C-1 **Charging Current and Proton Flux Measurements from Medium Earth**
1:05 PM **Orbit and the Slot Region**
A. Hands[1], K. Ryden[1], P. Morris[2], C. Dyer[3]
1. University of Surrey, United Kingdom
2. Airbus Defence and Space, United Kingdom
3. CSDRadConsultancy, United Kingdom

We present radiation measurements from the sister instruments Merlin and CREDANCE. 18 years of directly comparable data from medium Earth orbit and the slot region reveal new insights into the trapped radiation environment.

C-2 **Initial In-flight Error Rates for 16 MB SRAM as Flying on the Double**
1:20 PM **Asteroid Redirection Test (DART) Mission**
J. Likar[1], C. Pham[1], D. Wilson[1], A. Coburger[1], J. Atchison[1], J. Porter[1]
1. JHU APL, USA

Initial in-flight SRAM SBE error rates are compared to a series of rate prediction methods in an effort to demonstrate methods for uncertainty propagation and reduction.

C-3 **Single Event Effects and Total Dose Considerations for NASA's Interstellar**
1:35 PM **Probe mission**
J. Likar[1], M. Donegan[1], J. Porter[1], J. Kinnison[1], A. Haapala[1]
1. JHU APL, USA

Single event effects and total ionizing dose design and operational impacts are considered for an ambitious, >50 year, mission to the Local Interstellar Medium.

1:50 PM – 2:30 PM BREAK
EXHIBIT HALL A-B-C

SESSION D **BASIC MECHANISMS AND RADIATION EFFECTS**
2:30 PM SESSION INTRODUCTION
Chair: Daisuke Kobayashi, ISAS/JAXA

D-1 **Non-Linear Coupling Effects in Fully Depleted SOI Transistors**
2:35 PM
M. Spear[1], H. Barnaby[1], T. Wallace[1], J. Solano[1], D. Wilson[1], O. Forman[1], I. Sanchez Esqueda[1], A. Privat[2], M. Turowski[3], R. VonNiederhausern[4]
1. Arizona State University, USA
2. IceMOS Technology Corporation, USA
3. Alphacore Inc., USA
4. Air Force Research Lab., USA

Experimental results are shown that do not fit the standard threshold-voltage coupling factor between back and front gates in fully depleted SOI transistors. A new derivation of the coupling factor is derived.

D-2 2:50 PM

Low-Frequency Noise and Border Traps in Irradiated nMOS and pMOS Bulk Si FinFETs With SiO_2/HfO_2 Gate Dielectrics

K. Li[1], X. Luo[1], M. Rony[1], M. Gorchichko[1], G. Hiblot[2], S. Huylenbroeck[2], A. Jourdain[2], M. L. Alles[1], R. A. Reed[1], E. X. Zhang[1], D. M. Fleetwood[1], R. D. Schrimpf[1]

1. Vanderbilt University, USA

2. imec, Belgium

Temperature and gate-voltage dependencies of 1/f noise are compared in irradiated nMOS and pMOS FinFETs. Differences are found in the energy dependence of near-interfacial electron and hole traps in SiO_2/HfO_2 gate dielectrics.

D-3 3:05 PM

Total-Ionizing-Dose Effects and Low Frequency Noise in N-type Carbon Nanotube Field-Effect Transistors with HfO_2 Gate Dielectrics

P. Darmawi-Iskandar[1], A. Aaron[1], E. X. Zhang[1], B. L. Bhuva[1], J. S. Kauppila[1], J. L. Davidson[1], M. L. Alles[1], D. M. Fleetwood[1], L. W. Massengill[1]

1. Vanderbilt University, USA

TID irradiation leads to significant radiation-induced charge trapping in carbon nanotube FETs. Percolation-path switching and border traps contribute to low-frequency noise, with a more prominent role for border traps after irradiation.

D-4 3:20 PM

The Effect of 20 MeV Electron Radiation on Long Term Reliability of SiC Power MOSFETs

K. Niskanen[1], A. Javanainen[1], H. Kettunen[1], M. Lahti[1], M. Rossi[1], J. Jaatinen[1], D. Soderstrom[1], S. Lüdeke[1]

1. University of Jyväskylä, Finland

The effect of 20 MeV electron radiation on the lifetime of the silicon carbide power MOSFETs was investigated. Accelerated stress was applied on the pristine and irradiated devices and time-to-breakdown of gate oxide were compared.

D-5 3:35 PM

In-Situ Measurement of 1.8MeV Proton Radiation Effects on Comb-Drive MEMS Resonators

J. Lee[1], M. McCurdy[2], R. Reed[2], R. Schrimpf[2], M. Alles[2], P. Feng[1]

1. University of Florida, USA

2. Vanderbilt University, USA

We report on the first in-situ measurement of proton radiation effects on vibrating comb-drive microelectromechanical resonators built on silicon-on-insulator (SOI) technology. The devices exhibit high responsivity to proton radiation while maintaining robust resonance operations.

POSTER PAPERS

PD-1

Transient Measurement of Radiation-Induced Interface Traps Based on Non-Equilibrium Body Potential Under Pseudo-MOSFET Configuration

T. Zhang[1], F. Liu[2], Y. Huang[2], S. Chen[2], J. Zhang[2], X. Zhang[2], Y. Li[2], Y. Wang[2], Z. Zheng[2], F. Zhao[2], B. Li[2]

1. Institute of Microelectronics and Key Laboratory of Science and Technology on Silicon Devices, Chinese Academy of Sciences, University of Chinese Academy of Sciences, China

2. Institute of Microelectronics and Key Laboratory of Science and Technology on Silicon Devices, Chinese Academy of Sciences, China

A new transient method has been adapted to estimate the interface-trap density induced by radiation for SOI. This method relies on non-equilibrium body potential, which shows advantages in fast testing and simple data processing.

PD-2 **Correlating Percent In-Package Hydrogen to Hydrogen Concentration in Oxide After Ionizing Radiation Exposure**

P. Apsangi[1], S. Roark[1], A. Privat[1], H. Barnaby[1], H. Hjalmarson[2], K. Muthuseenu[1], K. Holbert[1]

1. Arizona State University, USA

2. Sandia National Laboratories, USA

Radiation-induced interface trap buildup is a strong function of hydrogen content in the semiconductor materials, which is quantitatively mapped to percent of hydrogen in the semiconductor packaging using a combination of experimental and simulation-based approaches.

PD-3 **Transient Photocurrent from High-Voltage Vertical GaN Diodes Irradiated with Electrons: Simulations and Experiments**

S. Koukourinkova-Duncan[1], W. Wampler[1], A. Colon[1], B. Doyle[1], G. Vizkelethy[1], G. Pickrell[1], E. Bielejec[1]

1. Sandia National Laboratories, USA

Simulations of the transient photocurrent in gallium nitride vertical diodes produced by electron irradiation are compared to experimental results. The simulations uncover the true diode response and physical mechanisms obscured by circuit effects in experiments.

PD-4 **Improvement in Performance of Carbon Nanotube Field-Effect Transistors Under Electron Irradiation**

M. Li[1], H. Zhu[1], S. Chen[1], Y. Tang[1], H. Shu[1], S. Peng[2], B. Li[1], J. Zhang[3], F. Zhao[1]

1. Institute of Microelectronics and Key Laboratory of Science and Technology on Silicon Devices, Chinese Academy of Sciences, China

2. High-Frequency High-Voltage Device and Integrated Circuits R&D Center, Institute of Microelectronics, Chinese Academy of Sciences, China

3. School of Information Science and Technology, North China University of Technology, China

Effects of electron irradiation on CNT-FETs were investigated. Significant improvements in device uniformity and electrical parameters were observed. The decomposition of organics and adsorbates on CNT surface after irradiation contributes to the device performance improvement.

3:50 PM END OF TUESDAY SESSIONS

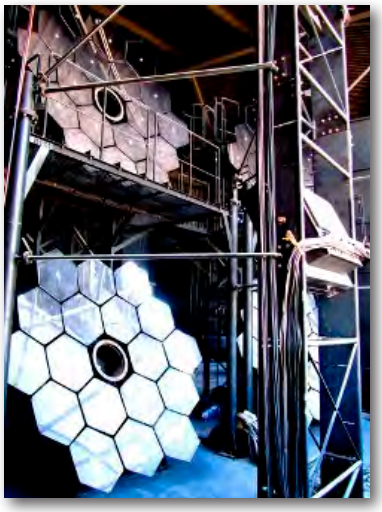
5:30 – 7:00 PM
EXHIBITOR RECEPTION

EXHIBIT HALL A-B-C

BALLROOM B-C
INVITED TALK
8:30 - 9:35 AM

Ultra High Energy Cosmic Rays in Utah

Pierre Sokolsky, Distinguished Professor of Physics and Astronomy Emeritus, University of Utah, Salt Lake City, Utah



The flux of cosmic rays bombarding the Earth's atmosphere from beyond our solar system extends over eleven orders of magnitude to above 10^{20} eV. The study of the highest energy cosmic rays (above 10^{17} eV) is difficult because of the extremely low flux (1/km^2/century at the highest energies). Detection techniques which can cover thousands of square kilometers have been developed to pursue this. I will describe the pioneering research done in Utah over the last 40 years utilizing the air fluorescence technique as well as very large area ground arrays of scintillation detectors. Since the 1980s a series of experiments, the Fly's Eye, the High-Resolution Fly's Eye, the Telescope Array, and Telescope Array x 4, have been deployed in the west deserts of Utah. Results from these experiments, as well as the complementary Auger detector array in Argentina, have helped to elucidate the nature and origin of these mysterious particles. Recent data point to an extra-galactic origin, associated with the large-scale structure of the universe. However, significant puzzles remain, including the observation of a few extraordinary events of macroscopic energy (3.6 x 10^{20} eV or ~ 50 Joules) which do not seem to be associated with any known sources.

Pierre Sokolsky, Distinguished Professor of Physics and Astronomy Emeritus at the University of Utah, received his PhD in Experimental Particle Physics from the University of Illinois in 1973. He was an Assistant Professor at Columbia University where he was involved in pioneering neutrino experiments at Brookhaven National Laboratory. In 1982, he moved to the University of Utah to join the Fly's Eye Detector group that was developing the first successful implementation of the atmospheric air-fluorescence technique to study ultra-high energy cosmic rays. Since then, he has played a leading role in a series of upgrades and expansions of the technique, including the High-Resolution Fly's Eye (HiRes), Telescope Array (TA), Telescope Array Low Energy Extension (TALE), and the Telescope Array expansion (Tax4).

This series of experiments resulted in significant discoveries relating to the nature of ultra-high energy cosmic rays. These include the first observation of the Greisen-Zatsepin-Kuzmin cutoff in the cosmic ray spectrum, predicted to occur due to the interaction of particles with the cosmic black-body radiation, the determination of the cosmic ray composition, and the observation of significant anisotropy in the arrival direction of cosmic rays in the Northern Hemisphere.

He is a Fellow of the American Physical Society, and has received Sloan Foundation and Guggenheim Foundation Fellowships. Recipient of the Wolfgang Panofsky Prize of the American Physical Society for the development of the air fluorescence technique, he is the author of the book "Introduction to Ultrahigh Energy Cosmic Ray Physics" and co-editor of "Large Area Networked Detectors for Particle Astrophysics." He was Chair of the University of Utah Physics Department from 2002 to 2006 and Dean of the College of Science from 2007-2014.

BALLROOM B-C

SESSION E **HARDNESS ASSURANCE**

9:35 AM SESSION INTRODUCTION

Chair: Christian Poivey, ESA

E-1 9:40 AM **Detection of Single Event Transients in Arbitrary Waveforms Using Statistical Window Analysis**

J. Carpenter[1], B. Dean[1], R. Young[1], S. Lawrence[1], D. Reising[1], D. Loveless[1]

1. University of Tennessee at Chattanooga, USA

A statistical window-analysis methodology, Ionizing Radiation Effects Spectroscopy (IRES), is demonstrated to detect anomalies within arbitrary waveforms. IRES does not require thresholding and identifies SETs within analog, digital, and RF signals.

E-2 9:55 AM **Correlation on Different Radiation Sources for Neutron-Induced SE tests at the 5-nm Node**

Y. Chiang[1], B. Bhuva[2]

1. Taiwan Semiconductor Manufacturing Company, Ltd., Taiwan

2. Vanderbilt University, USA

The work presents the correlation on SEU test between terrestrial neutrons, D-T neutrons, and protons by Monte-Carlo simulation and silicon validation in N5 flip flop. D-T neutron is recommended to proxy terrestrial neutron.

POSTER PAPERS

PE-1 **Fragmented High-Energy Heavy Ion Beams for Electronics Testing**

R. Garcia[1], K. Bilko[1], F. Cerutti[1], A. Coronetti[1], L. Esposito[1], S. Francesc[1], W. Andreas[1], F. Saigne[2]

1. CERN, Switzerland

2. Institut d'Electronique du Sud, Université de Montpellier II/CNRS, France

Fragmented heavy ion beams obtained from the interaction of highly energetic ions with cm thick targets are proposed to mimic the LET spectrum present in space and test electronics.

PE-2 **Monte-Carlo Tools for Assessing SEE Data Quality for Different Types of Analyses**

R. Ladbury[1]

1. NASA GSFC, USA

We apply a Monte-Carlo tool using a simplified GLM SEE data-fitting routine to assess how data quality affects SEE rate bounding, estimation and determination of fit parameters for σ vs. LET.

PE-3 **Comparison of Neutron Radiation Testing Approaches for a Complex SoC**

W. Stirk[1], E. Poff[1], J. Smith[1], J. Goeders[1], M. Wirthlin[1]

1. BYU, USA

We present bare-metal and Linux approaches to measuring the radiation sensitivity of SoC devices. The methods test individual components in round-robin fashion. Results from both methods match each other and expected values, supporting their validity.

10:10 AM – 10:40 AM BREAK
EXHIBIT HALL A-B-C

SESSION F **PHOTONIC DEVICES AND INTEGRATED CIRCUITS**
10:40 AM SESSION INTRODUCTION
Chair: Cedric Virmontois, CNES

F-1 **Proton-Induced Displacement Damage in 2D and Stacked CMOS**
10:45 AM **SPADs: Study of DCR Degradation**
A. Jouni[1,2,3], M. Sicre[2], V. Malherbe[2], B. Mamdy[2], J. Belloir[1], D. Soussan[2], S. De Paoli[2], G. Gasiot[2], V. Goiffon[3], V. Lalucaa[1], V. Lorquet[2], C. Virmontois[1]
1. CNES, France
2. STMicroelectronics, France
3. ISAE-SUPAERO, France

Displacement damage effects produced by proton irradiation on 40-nm CMOS SPADs are studied for different biasing conditions. Mean dark count rate increase and activation energy measurements are performed to characterize the induced bulk defects.

F-2 **Electric Field Enhanced Generation Current in Proton-Irradiated**
11:00 AM **InGaAs Photodiodes**
M. Benfante[1,2,3,4], O. Gilard[2], J. Reverchon[1], C. Durnez[2], V. Goiffon[3], S. Demiguel[4], T. Dartois[4], C. Virmontois[2]
1. III-V Lab, France
2. CNES, France
3. ISAE Supaero, France
4. Thales Alenia Space, France

The degradation of the dark current due to proton irradiation is studied on InGaAs PIN photodiodes. The combination of dark current and capacitance measurements allows extracting an electric field dependent damage factor.

F-3 **Design, Annealing, and Electric Field Effects on a Proton Irradiated**
11:15 AM **MWIR HgCdTe Focal Plane Array**
S. Dinand[1], N. Baier[2], E. De Borniol[2], C. Durnez[3], V. Goiffon[4], O. Gravrand[2], S. Rizzolo[5], O. Saint-Pé[5], C. Virmontois[3]
1. Airbus DS, CEA Leti, ISAE-SUPAERO, France
2. CEA-Leti, France
3. CNES, France
4. ISAE-SUPAERO, Université de Toulouse, France
5. Airbus Defense and Space, France

This work presents the performance degradation of a multi pixel-designs n/p mid-wavelength infrared HgCdTe focal plane array, induced by both total ionizing dose and displacement damage dose through proton irradiation and annealing.

F-4 11:30 AM

Influence of the Irradiation Protocol on the Degradation of the Electrical Performances of MidWave InfraRed T2SL Detectors

C. Bataillon[1], J. Perez[1], R. Alchaar[1], O. Saint-Pe[2], O. Gilard[3], P. Christol[1]

1. Institut d'Electronique et des Systèmes, France

2. Airbus Defense and Space, France

3. Centre National des Etudes Spatiales, France

Irradiations were performed with 60 MeV protons and fluences up to $8x10^{11}$ H^+/cm^2 on T2SL detector at 100 K or 300 K, showing a different degradation of the electrical performances according to the temperature of detector during irradiation.

F-5 11:45 AM

Temperature Dependence of Radiation-Induced Attenuation of Fluorine- Doped Optical Fibers at InfraRed Wavelengths

A. Morana[1], C. Campanella[1], G. Melin[2], T. Robin[2], E. Marin[1], A. Boukenter[1], Y. Ouerdane[1], S. Girard[1]

1. Laboratory Hubert Curien, France

2. iXblue, France

Combined temperature and radiation effects on F-doped fiber transmission in the IR are studied between -80 °C and 80 °C, up to 10 kGy(SiO_2) dose. Losses are slightly higher at -80 °C than at 20 °C.

POSTER PAPERS

PF-1

Radiation Effects on Microlenses, Color Filter Arrays, and Polarizing Filters in CMOS Image Sensor

C. Virmontois[1], A. Antonsanti[1,2], V. Lalucaa[1], C. Durnez[1], P. Panuel[1], V. Goiffon[2], M. Estribeau[2], O. Saint-Pé[3], E. Berdin[3], F. Larnaudie[3], L. Chavanne[1], J. Belloir[1]

1. CNES, France

2. ISAE-SUPAERO, France

3. Airbus, France

In addition to providing insights on dark current degradation after irradiation in modern CIS, this work studies the response of optical systems at the pixel level such as color filter arrays, polarized filters, and microlenses.

PF-2

Characterization of Single-Photon Avalanche Diodes Under High Proton Irradiation

M. Wu[1], E. Ripiccini[1], C. Fenoglio[1], F. Gramuglia[1], P. Keshavarzian[1], E. Kizilkan[1], E. Charbon[1]

1. EPFL, Switzerland

We characterized SPAD under 10 and 100 MeV proton irradiation up to DDD of 1 PeV/g. We focused our study on DCR and after-pulsing, which appear to be sensitive to low-energy protons and high flux.

PF-3

Laser Annealing Protocols for Healing Radiation-Damaged Single-Photo Detectors

J. Krynski[1], N. Sultana[1], Y. Lee[2], T. Jennewein[1], J. Lim[1], V. Makarov[1,3]

1. University of Waterloo, Canada

2. Photonic Inc., Canada

3. Russian Quantum Center, Russian Federation

Radiation-induced dark count rate in previously irradiated silicon avalanche photo diodes is significantly reduced in a thermal vacuum environment through annealing of the detector active area with a high-power laser using varying annealing protocols.

PF-4 **Direct Measurement of Total-Ionizing-Dose-Induced Phase Shift in Commercial, Integrated Silicon-Photonic Waveguides**

G. Tzintzarov[1], J. Teng[1], D. Nergui[1], S. Lalumondiere[2], D. Monahan[2], J. Cressler[1]

1. Georgia Tech, USA

2. Aerospace Corporation, USA

Silicon photonic waveguides were exposed to a micro-beam x-ray source. Non-monotonic radiation-induced phase shifts were measured. Causes and physical mechanisms are discussed.

PF-5 **Functionalized Microstructured Optical Fiber for Magnetic-field Sensing in Radiation Environments**

A. Dufour[1], D. Jamon[1], E. Marin[1], S. Neveu[2], F. Arnould[1], A. Morana[1], S. Girard[1], F. Royer[1]

1. Laboratoire Hubert Curien, France

2. Laboratoire PHENIX, France

A functionalized microstructured optical fiber displaying important polarimetric magneto-optical effects underwent 350 kGy X-ray irradiation with a 10 Gy/s(SiO_2) dose rate. In-situ effects were monitored to study its resistance to harsh environments.

PF-6 **Linear and Nonlinear Optical Properties of Fused Silica and Sapphire in Extreme Radiation and Thermal Environments**

B. Morgan[1], M. Van Zile[2], C. Petrie[3], P. Sabharwall[4], M. Burger[1], I. Jovanovic[1]

1. University of Michigan, USA

2. Ohio State University, USA

3. Oak Ridge National Laboratory, USA

4. Idaho National Laboratory, USA

We report the initial results from post-irradiation examination of bulk optical materials exposed to simultaneous effects of irradiation and thermal annealing, examined by a Z-scan experiment to measure nonlinear optical properties, and linear absorption experiment.

PF-7 **Perovskite $CsPbBr_3$ Single Crystal Detector Stability and Polarization Under High Flux X-ray irradiation**

L. Pan[1], Y. He[1], I. Pandey[1], A. Miceli[2], D. Chung[2], V. Klepov[1], M. De Siena[1], M. Kanatzidis[1,2]

1. Northwestern University, USA

2. Argonne National Laboratory, USA

The performance, regarding signal stability and polarization, of melt grown $CsPbBr_3$ detectors under X-ray flux of 10^5-10^9 photons/s/mm^2 was experimentally investigated with detector working in pulse mode or current mode.

PF-8L **Influence of ambient light on the radiation-induced attenuation of germanosilicate optical fibers at the telecommunication wavelengths**

C. Campanella[1], A. Morana[2], A. Meyer[3], F. Mady[4], M. Benabdesselam[4], H. Desjonqueres[5], S. Poirier[5], C. Monsanglant-louvet[5], E. Marin[2], Y. Ouerdane[2], A. Boukenter[2], S. Girard[6]

1. Laboratoire Hubert Curien, France
2. Laboratory Hubert Curien, France
3. Université Jean Monnet, France
4. Institut de Physique de Nice, France
5. Institut de Radioprotection de Sûrete Nucléaire (IRSN), France
6. Université de Saint Etienne, France

The influence of ambient light on the Radiation-Induced Attenuation (RIA) levels and kinetics of germanosilicate optical fibers at the telecommunication wavelengths is investigated, revealing the importance of this environmental parameter when performing RIA measurements.

EXHIBIT HALL A-B-C
12:00 PM – 1:30 PM EXHIBITOR LUNCH AND RAFFLES

RADIATION EFFECTS DATA WORKSHOP
1:30 PM - 4:30 PM
CASCADE C-D-E

INTRODUCTION

Chair: Zachary Fleetwood, SpaceX

DW-I **Neutron-Induced SEEs in the Xilinx Versal Prime**

H. Quinn[1], C. Corley[2], P. Thelen[3]

1. LANL, USA
2. University of Texas, USA
3. SNL, USA

Results for neutron testing of the 7-nm Xilinx Versal Prime are presented. Results show an improvement in neutron sensitivity from previous Xilinx parts and other manufacturer's microprocessors.

DW-2 **Proton Induced Single Event Effects on the Arria 10 Commercial Off-the-Shelf CMOS Field Programmable Gate Array**

R. Koga[1], S. Davis[1], A. Yarbrough[1], J. Shanney[1], K. Pham[1], C. Cao[1], K. Pham[1]
1. The Aerospace Corporation, USA

We present observations of proton induced single event effects on the Arria 10 commercial off-the-shelf CMOS FPGA at three proton energy levels. The SRAM-based FPGA was sensitive to protons below 50 MeV.

DW-3 **64MeV Proton Single-Event Evaluation of Xilinx Single Event Mitigation (XilSEM) Firmware on Xilinx 7-nm ACAP Devices**

Y. Chen[1], P. Maillard[1], R. Devi Veggalam[1], S. Reddy Madem[1], E. Crabill[1], J. Barton[1], M. Voogel[1]
1. Xilinx, Inc, USA

Xilinx Single Event Mitigation (XilSEM) firmware shows SEFI immunity on Xilinx 7nm ACAP™ characterized using a 64 MeV proton source. XilSEM CRAM scrubbing and NPI scanning functionality and error coverage is presented.

DW-4 **Neutron and > 60MeV Proton Characterization of Xilinx 7nm VersalTM Multicore Scalar Processing System (PS)**

P. Maillard[1], Y. Chen[1], J. Arver[1], A. Shui[1], M. Voogel[1], V. Merugu[1]
1. Xilinx, Inc, USA

This paper presents the single event response of Xilinx's 7nm Versal™ multicore scalar processing system (PS) using Xilinx System Validation Tool (SVT) design suite. SEU, SEFI and SEL results are presented.

DW-5 **Compendium of Current Heavy Ion Single-Event Effects Test Results for Candidate Electronics for NASA Johnson Space Center**

J. Pritts[1], R. Gaza[1], C. Bailey[1], N. Kyson[1]
1. NASA JSC, USA

We present radiation effects test results and analysis produced by NASA JSC in 2021 for candidate electronic components and devices. Devices tested include integrated circuits, MOSFETs, DC-DC converters, and various commercial solutions.

DW-6L **Extended Compendium of Total Ionizing Dose (TID) Test Results for the Europa Clipper Mission**

S. Zajac[1], A. Bozovich[1], R. Davies[2], A. Woo[1], B. Rax[1], J. Davila[1], D. Nguyen[3], W. Parker[1], A. Kenna[1], J. Thomas[1]
1. NASA JPL, USA
2. University of St. Thomas, USA
3. Northrop Grumman, USA

Results of total ionizing dose (TID) tests and analysis on Electric, Electronic, and Electromechanical (EEE) parts, performed by the Jet Propulsion Laboratory in support of the Europa Clipper Mission.

DW-7 **A Study of Neutron Induced Single-Event Damage in AlGaN/GaN HEMTs**

H. Gao[1], D. Ahsanullah[1], R. Baumann[1], B. Gnade[1]

1. Southern Methodist University, USA

Accelerated neutron study results of gallium nitride power devices are reported. Hundreds of devices were irradiated while stressed with drain voltages of up to 400V. The observed failures enable an accurate assessment of terrestrial reliability.

DW-8L **100SW1502 Optocoupler TID & DDD Tests**

Z. Olson[1], R. Monreal[1], J. Vloet[1]

1. Southwest Research Institute, USA

A novel optocoupler 100SW1502 was developed in-house and tested for various parameter degradations at doses up to 300 kRad TID and 1.510^{12} n/cm2 DDD.

DW-9 **Characterization of the Effects of 250 MeV Proton-Induced Total Ionizing Dose and Displacement Damage on the 66266 Optocoupler**

S. Messenger[1], M. Mishler[1], J. Hack[1], P. Dudek[1]

1. Northrop Grumman Corporation, USA

This paper explores the combined effects of total ionizing and displacement damage dose caused by 250 MeV protons on the Micropac 66266 optocoupler. Proton fluences up to 4×10^{12} p^+/cm^2 were used for this radiation test.

DW-10L **Single Event Effects Susceptibilities of Select Commercial-Off-The Shelf Components for Space**

D. Lo[1], T. Tran[1]

1. Northrop Grumman Systems Corporation, USA

We report the results of single event effects (SEE) testing with heavy ions of COTS (commercial-off-the-shelf) electronic components considered for space missions.

DW-11 **Single Event Upset and Total Ionizing Dose Response of 12LP FinFET Digital Circuits**

J. Neuendank[1], M. Spear[1], T. Wallace[1], D. Wilson[1], J. Solano[1], G. Irumva[1], I. Sanchez Esqueda[1], H. Barnaby[1], L. Clark[1], J. Brunhaver[1], M. Turowski[2], E. Mikkola[2], D. Hughart[3], J. Manuel[3], S. Agarwal[3], B. Vaandrager[3], G. Vizkelethy[3], M. King[3], M. Marinella[3]

1. Arizona State University, USA

2. Alphacore Inc, USA

3. Sandia National Laboratories, USA

Experimental results showing the total ionizing dose response of 12-nm bulk FinFET digital circuits to 60 keV x-ray are presented. Single event upset cross-sections vs. ion linear energy transfer for digital flip-flop chains are extracted.

DW-12 **SET Characterization of a High and Low Side Gate Driver (RIC7S113) Using Pulsed Laser and Heavy Ion Testing**

J. Warner[1], E. Faraci[2], C. Pham[1]

1. JHUAPL, USA

2. IR HiRel, an Infineon Technologies Company, USA

The SET response of the RIC7S113 gate driver was characterized using pulsed laser and heavy ion accelerator testing. The SET response between the two methods are compared.

DW-13 Neutron-Induced Single-Event Effects and Total Ionizing Dose Response in Embedded Radios

E. Auden[1], M. Caffrey[1]

1. Los Alamos National Laboratory, USA

Neutron-induced single-event effects, displacement damage, and total ionizing dose are characterized for a commercial-off-the-shelf embedded radio. The radio's radiation tolerance is investigated as part of an evaluation for possible spaceflight on short-term exploratory satellites.

DW-14 SEL and SEU In-Flight Data from Memories On-Board PROBA-II Spacecraft

C. Poivey[1], R. Harboe-Sorensen[2]

1. ESA, Netherlands

2. RHS consulting, Netherlands

This paper presents an analysis of the SEE in-flight data of memories on board Proba-II spacecraft. Proba-II spacecraft has been flying on a LEO orbit since November 2009. Observed in-flight error rates are compared with predictions based on ground test data.

DW-15 Total Ionizing Dose Response of Commercial 22-nm FD-SOI CMOS Technology

J. Solano[1], D. Wilson[1], T. Wallace[1], O. Forman[1], M. Spear[1], I. Sanchez Esqueda[1], H. Barnaby[1], A. Privat[1], N. Turowski[2], V. Rudolf[3]

1. Arizona State University, USA

2. Alphacore, USA

3. Spacecraft Component Branch, Air Force Research Lab, USA

Experimental results showing the response of 22-nm fully depleted silicon on insulator devices (FD-SOI) are presented. Gate voltage shift at a constant drain current is extracted and compared across all similar devices of varying widths.

DW-16 Debugging Xilinx Zynq-7000 SoC Processor Caches During Linux System Execution Under Proton Irradiation

J. Mattis[1], J. Budroweit[1], S. Ferdinand[1]

1. DLR e.V., Germany

In this paper we present a deeper insight on the CPU caches of a Zynq-7000 SoC, their influence in a running operating system and possible reasons for their malfunction by using a 230-MeV proton beam.

DW-17 Single Event Characterization of Power Components Under Heavy Ion Irradiation

N. Aksteiner[1], J. Budroweit[1]

1. DLR e.V., Germany

Three power control devices were characterized under heavy ion irradiation. Two LT3007 LDOs showed many transients and breakdown. A single sample of the LT8610 Buck converter showed significant transients. The ADM1270 hot-swap controller showed various SEE.

DW-18 TID and SEE Evaluation on a Universal Input, 10-Output Low Impedance LVCMOS Buffer

J. Budroweit[1], N. Aksteiner[1]
1. DLR e.V., Germany

This paper presents the latest TID and SEE test results of the Texas Instruments CDCLVC1310, a universal input, 10-output low impedance LVCMOS buffer.

DW-19 NASA Goddard Space Flight Center's Recent Radiation Effects Test Results

A. Topper[1], E. Wilcox[2], M. Casey[2], J. Barth[2], M. Joplin[2], M. Berg[1], T. Carstens[2], M. Campola[2], D. Cochran[1], M. Obryan[1], J. Pellish[2], P. Majewicz[2]
1. SSAI, USA
2. NASA GSFC, USA

Total ionizing dose, displacement damage dose, and single event effects testing were performed to characterize and determine the suitability of candidate electronics for NASA space utilization. Devices tested include FPGAs, optoelectronics, digital, analog, and bipolar devices.

DW-20 Radiation Assessment of Two Automotive-Grade N-Channel MOSFETs

J. Ward[1], J. Mckoy[1], I. Jeffrey[1], D. Ross[2], P. Ferguson[1]
1. University of Manitoba, Canada
2. Magellan Aerospace, Canada

Radiation assessment is performed for two automotive-grade N-MOSFETs for qualification for use in low Earth orbit satellites. Decreases in threshold voltage are observed during total dose screening. Parts may be suitable for use in low Earth orbit satellites.

DW-21 The Aerospace Corporation's Compendium of Recent Radiation Testing Results

S.C. Davis[1], A.D. Yarbrough[1], R. Koga[1], A.W. Wright[1], J.A. Shanney[1], K.G. Pham[1], C. Cao[1], K.G. Pham[1], S. Lin[1], B. Dooley[1]
1. The Aerospace Corporation, USA

Radiation testing was performed on several commercial components to determine the response of these components to the space radiation environment. Testing was performed using protons and heavy ions.

DW-22 Single Event Effects and Total Ionizing Dose Characterization of a 1.25Gbps LVDS Repeater

A. Turnbull[1], M. Von Thun[1], E. Serna[1], J. Yount[1]
1. CAES, USA

Single Event Latch-up (SEL), Single Event Transient and Total Ionizing Dose (TID) radiation characterization was performed on a CAES UT54LVDS454 1.25Gbps LVDS repeater. The device was shown to be suitable for space applications.

DW-23 **First Extensive Radiation Characterization of Double Capacitive SiO_2 Isolation Barrier Technology using TI's ISOS141-SEP as a Test Vehicle**

M. Saul[1], R. Gooty[1], S. Williams[1], S. Khan[1], K. Elnashar[1]
1. Texas instruments, USA

Double capacitive SiO_2 isolation is a modern system isolation solution with improved radiation results such as single event latchup, single event dielectric rupture, total ionizing dose, and neutron displacement damage.

DW-24 **Radiation Evaluation of the TPS7H4010-SEP Step-Down Voltage Converter**

T. Lew[1], J. Cruz-Colon[1], A. Marinelarena[1], N. Cunningham[1]
1. Texas Instruments, USA

Single events effects (SEE) characterization results for TPS7H4010-SEP Step-Down Converter are summarized, showing very robust SEE performance up to LET_{EFF}=43 MeV-cm^2/mg.

DW-25 **A Heavy-Ion Single-Event Effects Test Facility at Michigan State University**

S. Lidia[1], T. Glasmacher[1], S. Kim[1], G. Machicoane[1], P. Ostroumov[1], A. Stolz[1]
1. Facility for Rare Isotope Beams, Michigan State University, USA

Michigan State University has commissioned a new SEE test facility based on the recently completed Facility for Rare Isotope Beams superconducting LINAC. We review the facility design, capabilities, and commissioning status.

DW-26 **Displacement Damage and Total Ionizing Dose at High and Low Dose Rate Performance of an Optocoupler**

Z. Yang[1], D. Hiemstra[2], S. Shi[1], C. Jin[1], Z. Li[1], L. Chen[1]
1. University of Saskatchewan, Canada
2. MDA, Canada

Results of proton and Cobalt-60 irradiation of an optocoupler are presented. Performance in the space radiation environment is discussed.

DW-27 **Single Event Upset Characterization of the Intel Movidius Myriad X VPU and Google Edge TPU Accelerators Using Proton Irradiation**

D. Ramaswami[1], D. Hiemstra[2], Z. Yang[1], S. Shi[1], L. Chen[1]
1. University of Saskatchewan, Canada
2. MDA, Canada

Proton induced SEU cross-sections of the Movidius Myriad X VPU and Google Edge TPU are presented. Upset rates in the space radiation environment are estimated and found to be acceptable for low orbit missions.

DW-28 **Guide to the 2021 IEEE Radiation Effects Data Workshop Record**

D. Hiemstra[1]
1. MDA, Canada

The 2021 Workshop Record has been reviewed and a table prepared to facilitate the search for radiation response data by part number, type, or effect.

DW-29 **Total Dose Performance at High Dose Rate of Isolated Switching Regulator Evaluation Kits**

D. Hiemstra[1], S. Shi[2], L. Chen[2]

1. MDA, Canada

2. University of Saskatchewan, Canada

Results of Cobalt-60 high dose rate irradiation of isolated switching regulator evaluation kits are provided. Their performance in the space radiation environment is discussed.

DW-30 **Single Event Effect Measurements of Micron Technology 128Gb Single-Level NAND Flash Memory**

F. Irom[1], G. Allen[1]

1. Jet Propulsion Laboratory, USA

Heavy ion single-event measurements on 128Gb Micron Technology single-level NAND flash memory are reported. Two single event effects phenomena were investigated: single bit upsets and single effect functional interrupts.

DW-31 **Neutron Induced Displacement Damage in Commercial Power Management Integrated Circuits**

G. Koli[1], E. Auden[2], H. Quinn[2]

1. Arizona State University, USA

2. Los Alamos National Laboratory, USA

Atmospheric neutrons can produce damaging effects in power management integrated circuits (PMICs). Three commercial PMICs have been irradiated with neutrons to investigate displacement damage effects in low drop-out (LDO) and stepdown (Buck) voltage regulators.

DW-32 **Combined Neutron and TID Results of the Intersil ISL70321SEH**

W. Newman[1], N. van Vonno[1], L. Pearce[1], D. Turner[1]

1. Renesas, USA

We report the combined results of the ISL70321SEH after exposure to 5 x 10^{11}, 2 x 10^{12}, and 1 x 10^{13} neutrons/cm^2 followed by 100 krad(Si) HDR total ionizing dose.

DW-33L **Laser Techniques for Mitigation of Single Event Effects in a PWM Controller**

T. Bernard[1], E. Thomson[1], L. Pearce[1], H. Tim[1], A. Eberts[1]

1. Renesas Electronics America, USA

Presenting the results of the Buck PWM Controller Single Event Functional Interrupts (SEFI) on the initial silicon, and the efforts to discover root cause of the SEFI/SET through diagnostic testing, design simulations, and laser testing.

DW-34 **Radiation Results for Modern GaN-on-Si Power Transistors**

R. Strittmatter[1], B. Sun[1], S. Zhang[1], M. Zafrani[2], A. Lidow[1]
1. Efficient Power Conversion Corporation, USA
2. EPC Space, USA

GaN-on-Si power transistors launched in 2021 and early 2022 specifically designed for high radiation resistance and low dynamic on-resistance are characterized for single event and dynamic on-resistance, demonstrating improvement over all prior generation GaN-on-Si devices.

DW-35 **Single Event Effects Characterization of Microchip Programmable Current Limiting Power Switch LX7712**

M. Leuenberger[1], R. Stevens[1], D. Johnson[1], N. Rezzak[1]
1. Microchip Technology, USA

The heavy ions single event effect characterization results of Microchip Technology's radiation-hardened programmable current limiting power switch IC, the LX7712, are presented. The data shown are based on single event campaign of September 2021

DW-36 **Radiation Evaluation of the DP83561-SP Radiation Hardened, 10/100/1000 Ethernet PHY Transceiver with SEFI Handling Sub-System**

R. Gooty[1]
1. Texas instruments, USA

High reliability gigabit ethernet PHY transceivers designed for the high-radiation environment with SEFI handling sub-system radiation effects are evaluated.

DW-37 **Improving the Total Ionizing Dose and Single Event Performance of a High Voltage 180nm CMOS Trusted Foundry Process**

M. Hamlyn[1], I. Donnelly[1], A. Ghoshal[1], A. Quiroz[1]
1. Apogee Semiconductor, USA

Developing radiation hardened components in 180nm CMOS process is a challenge due to total ionizing dose (TID) effects. TID performance was improved from 30krad to 300krad using TID improved transistors and results will be shown.

DW-38 **Accelerated Nuclear Radiation Effects on the Raspberry Pi 3 B+**

C. Corley[1], H. Quinn[2], E. Swartzlander, Jr.[1]
1. University of Texas, USA
2. LANL, USA

The Raspberry Pi3B+ running Linux-derivative RaspberryPi OS and benchmarks was subjected to radiation testing in the neutron beam at LANSCE. Cross sections for SEUs, SEFIs, and crashes/hangs were recorded. Testing this complex system is discussed.

DW-39 **Raspberry Pi Zero and 3B+ SEE and TID Test Results**

S. Guertin[1], S. Vartanian[1], A. Daniel[1]
1. NASA JPL, USA

We report SEE and TID testing of Raspberry Pi Zero and Raspberry Pi 3B+ computers. SEFI modes, display errors, and file transfer failures dominated the responses.

DW-40 **Total Ionizing Dose and Reliability Evaluation of the ST-DDR4 Spin-Transfer Torque Magnetoresistive Random Access Memory (STT-MRAM)**

S. Vartanian[1], J. Yang-scharlotta[1], G. Allen[1], A. Daniel[1], F. Mancoff[2], D. Symalla[2], A. Olsen[2], D. Costanzo[1]

1. NASA Jet Propulsion Laboratory, USA

2. Everspin Technologies, USA

We present total ionizing dose (TID) evaluation of the Everspin Technologies 1Gb non-volatile ST-DDR4 spin-transfer torque MRAM, and its effects on the reliability of the magnetic tunnel junctions (MTJs).

DW-41L **Total-Ionizing-Dose Effects on Threshold Voltage Distribution of 64-Layer 3D NAND Memories**

M. Kumar[1], M. Raquibuzzaman[1], M. Buddhanoy[1], M. Wasiolek[2], K. Hattar[2], B. Ray[1]

1. University of Alabama in Huntsville, USA

2. Sandia National Laboratories, USA

We measure and model total-ionizing-dose induced threshold voltage (Vt) loss of commercial 64-layer TLC 3-D NAND memory using user-mode commands. Measured data shows Vt loss is linear with TID for the highest programmed Vt.

DW-42 **Total Dose and Ion Beam Radiation Response of Spin-Transfer Torque MRAM**

A. Cao[1], L. Wang[1], J. Zhang[1], C. Gou[1], L. Liu[1], X. Li[1], X. Bi[1], Z. Li[1], X. Han[1], B. Wang[2], Y. Zhao[1]

1. Beijing Microelectronics Technology Institute, China

2. The School of Integrated Circuit Science and Engineering, Beihang University, China

The total dose and ion beam radiation responses of a commercial STT-MRAM are evaluated. The results indicate that MTJ is inherently radiation tolerant, while the peripheral circuit exhibits soft errors during ion beam irradiation.

DW-43 **Temperature Control Equipment for SEE and TID Tests**

A. Bakerenkov[1], V. Felitsyn[2], P. Chubunov[1], A. Koziukov[1], N. Bondarenko[1], M. Maltseva[1]

1. Branch of JSC "United Rocket and Space Corporation" - "Institute of Space Device Engineering", Russian Federation

2. National Research Nuclear University MEPhI (Moscow Engineering Physics Institute), Russian Federation

Equipment for temperature control of integrated circuits in the range from -60 °C to +125 °C during radiation tests was developed and described. The equipment can be used for both SEE and TID tests.

4:30 PM END OF WEDNESDAY SESSIONS

6:00 PM (Busses leave 5:30 - 5:50 PM) **CONFERENCE SOCIAL**

Technical Program Thursday

CASCADE A-B
7:00 - 8:15 AM

BREAKFAST WITH YOUNG PROFESSIONALS PRESENTATION
(Ticket Required to Attend)

BALLROOM B-C
INVITED TALK
8:30 - 9:30 AM

Dinosaurs and other Mesozoic critters of Utah – A trip through Deep Time

Professor Brooks Britt, Chair, Geological Sciences, Brigham Young University, Provo, Utah

Utah has long been renowned for its dinosaurs and spectacular geology. I will show you how the BYU Museum of Paleontology's team of paleontologists collects dinosaurs and their cohorts, what the rocks that contain their bones reveal about the ancient environments in which they lived, and how we obtain the ages of the rocks. Contrary to what you've seen in movies, where the rock is quickly brushed from the bones, I will show the reality of excavating – which involves giant bulldozers, high-explosives, and CAT-scans to extract the bones from their stony tombs. Finally, you will learn about a spectacular fossil site located on the edge of a cliff in northeastern Utah - the Saints & Sinners Quarry. There, over 20,000 bones have been collected. These bones represent an array of animals, ranging from dinosaurs to pterosaurs to drepanosaurs. All died of dehydration, along the shores of a drying oasis. This oasis was surrounded by dunes hundreds of feet high in the midst of a desert covering 2.2 million square kilometers some 208-million-years ago.

Brooks is from the Tacoma/Seattle area of Washington State. At the age of 14 he and a cousin planned and executed a dinosaur hunting expedition via bicycle near Vernal, Utah. They found and opened a dinosaur site the first day and they operated it over three summers. Both became paleontologists.

He obtained bachelor's and master's degrees from Brigham Young University (BYU) and a Ph.D. from the University of Calgary/Royal Tyrrell Museum of Paleontology in Alberta, Canada. Before returning to BYU as a professor he was a museum curator and a museum director.

He has worked primarily on theropod and sauropod dinosaurs, but his current focus is a Late Triassic fauna from northeastern Utah and the Early Cretaceous Cedar Mountain Formation fauna.

BALLROOM B-C
SESSION G
9:30 AM

DOSIMETRY
SESSION INTRODUCTION
Chair: Ethan Cascio, Massachusetts General Hospital

G-1 9:35 AM

Charge Collection in SOI Microdosimeters and Their Radiation Hardness

V. Pan[1], L. Tran[1], Z. Pastuovic[2], D. Hill[1], J. Williams[1], M. Povoli[3], A. Kok[3], S. Peracchi[2], D. Boardman[2], S. Guatelli[1], M. Petasecca[1], M. Lerch[1], A. Rosenfeld[1]

1. University of Wollongong, Australia

2. ANSTO, Australia

3. SINTEF, Norway

A negative pulse has been observed in a new batch of SOI microdosimeters originating from the substrate. CCE studies have been conducted to investigate this pulse as well as radiation hardness studies on the device.

G-2 9:50 AM

Mirror-Assisted Radioluminescent Optical Fibers for X-ray Beam Monitoring

J. Vidalot[1],[2], F. Fricano[2], A. Morana[2], C. Campanella[2], D. Lambert[1], J. Michalon[2], Y. Ouerdane[2], A. Boukenter[2], M. Raine[1], P. Paillet[1], S. Girard[2]

1. CEA / université Jean Monnet St Etienne, France

2. Laboratoire Hubert Curien - université Jean Monnet - CNRS UMR 5516 - IOGS - St Etienne - France

We investigate the performances of an Aluminum mirror-assisted radioluminescent nitrogen-doped optical fiber to monitor X-ray fluxes from 0.05 to 1.5 Gy/s.

G-3 10:05 AM

Towards an Embedded and Distributed Optical Fiber-based Dosimeter for Space Applications

A. Meyer[1], A. Morana[1], L. Weninger[1], N. Balcon[2], G. Mélin[3], J. Mekki[2], T. Robin[3], A. Champavère[4], F. Saigné[5], J. Boch[5], T. Maraine[5], A. Aït-ali-saïd[6], E. Marin[1], Y. Ouerdane[1], A. Boukenter[1], S. Girard[1]

1. Université Jean Monnet, France

2. CNES, France

3. iXblue, France

4. GuidOptix, France

5. Université de Montpellier, France

6. TRAD, France

We investigated the performance under γ and X-rays of an optical-fiber-based distributed dosimeter consisting of an embedded Optical Time-Domain Reflectometry (OTDR) interrogator operating at 1610 nm and a phosphorus-doped, single-mode, size-reduced optical fiber.

POSTER PAPERS

PG-1

New Real-Time Fluence Correction Method with SRAM Dosimeter for High Accuracy Single-Event Effect Evaluation System

R. Yoon[1], D. Bae[1], K. Kim[1], S. Chung[1], H. Lee[1], S. Woo[1], C. Cho[1], J. Yoo[1], S. Wender[2], Y. Kim[1]

1. QRT, Republic of Korea

2. LANSCE, USA

Even when there is no beam information, we propose SEE system including reference dosimeter and generalization equation that can be reflected in the SEU measurement with real-time beam analysis.

10:20 AM – 10:50 AM NORTH & EAST PRE-FUNCTION — BREAK

SESSION H — **HARDENING BY DESIGN**
10:50 AM — SESSION INTRODUCTION
Chair: Ethan Cannon, Boeing

H-1 10:55 AM — **An RHBD FPGA with Distributed SEU Sensors, Embedded Error Handler, and Embedded MRAM Configuration Storage in 22nm FinFET CMOS**

O. Kibar[1], A. Atli[2], P. Mohan[2], M. King[3], K. Mai[2]
1. Nvidia, USA
2. Carnegie Mellon University, USA
3. Sandia National Laboratories, USA

This study examines the design and single-event response of a custom-designed RHBD FPGA in a 22nm bulk FinFET process that employs strike sensors and embedded MRAM configuration storage. Heavy-ion single-event upset testing results are presented.

H-2 11:10 AM — **A Radiation Tolerant Charge-Pump PLL with Low Static Phase Offset in 65nm CMOS technology**

J. Prinzie[1], S. Biereigel[2], S. Kulis[2], P. Leitao[2], R. Francisco[2], P. Moreira[2]
1. KU Leuven, Belgium
2. CERN, Switzerland

This paper presents a novel radiation tolerant charge-pump PLL with state-of-the-art static-phase error variability suitable for high-performance clock systems in high-dose radiation environments. The circuit has been experimentally verified with X-rays up to 180 Mrad.

H-3 11:25 AM — **Efficacy of Transistor Stacking on Flip-Flop SEU Performance at 22-nm FDSOI Node**

Z.-R. Li[1], C. Elash[1], C. Jin[1], L. Chen[1], M. Rathore[2], S.-J. Wen[2], R. Fung[2], J.-S. Xing[1], S.-T. Shi[1], Z.-W. Yang[1], B. Bhuva[3]
1. University of Saskatchewan, Canada
2. Cisco Systems, USA
3. Vanderbilt University, USA

SE performance of multiple flip-flop designs using the stacked-transistor technique at the 22-nm FDSOI technology is presented. Irradiation results show significant reductions in SE cross-sections for hardened designs compared to a conventional design.

POSTER PAPERS

PH-1 SE Performance of Schmitt-Trigger-Based Flip-Flops at 22-nm FDSOI Technology Node

Z.-R. Li[1], C. Elash[1], C. Jin[1], L. Chen[1], M. Rathore[2], S.-J. Wen[2], R. Fung[2], J.-S. Xing[1], S.-T. Shi[1], Z.-W. Yang[1], B. Bhuva[3]

1. University of Saskatchewan, Canada

2. Cisco Systems, USA

3. Vanderbilt University, USA

Multiple SE hardened flip-flop designs based on Schmitt-trigger circuits are presented. Alpha particles and heavy ions results show significant reductions in SEU cross-sections compared with the conventional design.

PH-2 A Single-Event Transient Mitigation Technique for Bandgap Reference Utilizing in Space Application

J. Liu[1], B. Liang[1], J. Chen[1], Y. Chi[1], D. Luo[1], Y. Guo[1]

1. National University of Defense Technology, China

This paper proposes a radiation-hardened-by-design (RHBD) technique targeting single-event transient (SET) mitigation in bandgap circuits. Laser experiments are conducted for evaluation, which illustrate that SET perturbations are almost eliminated with the proposed technique.

PH-3 Neutron Radiation Testing of Different TMR Soft Processors on SRAM-based FPGAs

A. Wilson[1]

1. Brigham Young University, USA

Soft processors are often used within FPGA designs in radiation hazardous environments. This paper presents neutron radiation results of five different TMR soft processors. The TMR processors achieved a 65x improvement in SEU-induced mean fluence.

PH-4 Vertical Integration of Physics-Based Radiation Models in a Hierarchical Integrated Circuit Design Flow

J. Kauppila[1,2], D. Vibbert[1], K. Warren[1,2], D. Ball[2], T. Haeffner[2], S. Vibbert[2], J. D'Amico[2], A. Watkins[2], E. Zhang[2], C. Moyer[1], A. Sternberg[2], L. Massengill[1,2]

1. Reliable MicroSystems, LLC, USA

2. Vanderbilt University, USA

A vertically integrated radiation aware design (VIRAD) approach is presented. The analysis methods are demonstrated on sub-50nm partially depleted SOI designs. Analysis results are compared to heavy ion test results on DICE flip flops.

Technical Program Thursday

CASCADE A-B
11:40 AM - 1:30 PM

LUNCH WITH WOMEN IN ENGINEERING (WIE) PRESENTATION
(Ticket Required to Attend)

POSTER SESSION
1:30 PM - 4:30 PM
BALLROOM B-C

INTRODUCTION

Chair: Jonathan Pellish, NASA

4:30 PM

END OF THURSDAY SESSIONS

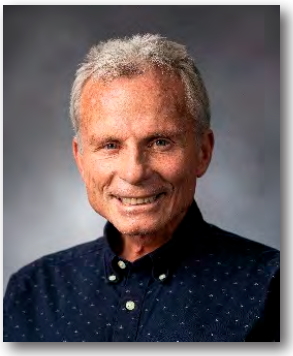
4:30 PM - 6:30 PM
BALLROOM B-C

RADIATION EFFECTS COMMITTEE ANNUAL OPEN MEETING

BALLROOM B-C
INVITED TALK
8:30 - 9:30 AM

Utah Rocks!

Ron Harris, Professor of Geological Sciences, Brigham Young University, Provo, Utah



Utah is the Ute Tribe word for people of the mountains. The mountains and canyons of Utah harbor many geological secrets of how Earth works. The secrets unfold like a journey back through time, through a palimpsest of former worlds encrypted in the crag.

Millions of visitors every year come to Utah to see its rocky landscapes. Disguised as 'scenery', the rocks reveal a story in pattern language of worlds where continents collide and rip apart, seas invade and retreat, land shaped by fire and ice, infusions of precious mineral and energy resources, deadly earthquakes, and some of Earth's largest volcanic explosions, and clues of how climates change. These events represent three phases of mountain building involving the accumulation, convergence, and collapse phases. Throughout the slow changes of land and sea, life evolved leaving fossil traces of everything from Earth's earliest single-celled life forms to its increasingly complex and diverse progeny.

My talk will not only provide a brief introduction to the geological evolution of Utah, but it will hopefully help you make geological interpretations of your own whereever you are.

Dr. Ron Harris is a Professor of Geological Sciences at Brigham Young University who specializes in mountain building processes and associated natural hazards. He was born and raised in Oregon and received his BSc. in Geological Sciences from the University of Oregon. He also has a master's degree in Geophysics from the Geophysical Institute of Alaska, and a Ph.D. in Geodynamics from University College London in the U.K.

Ron has worked for oil, mining, and environmental companies, for the US Geological Survey, and with the governments of several developing countries threatened by natural hazards. Dr. Harris' research in geodynamics integrates many sub-disciplines including neotectonics, structural geology, petrology, geochemistry, geochronology, geophysics, and computer modeling. Dr. Harris has taught at universities in the U.S., Great Britain, Oman, Taiwan and Indonesia. He has been invited to make over 200 presentations, has more than 75 peer-reviewed publications and garnered several research grants and awards. He recently published the second edition of his book about hiking the geology of the Wasatch Range, which is written for those who know very little about geology. ***https://linuslearning.com/product/exploring-the-geology-of-little-cottonwood-canyon/***

Perhaps the most distinguishing feature of Dr. Harris' career is his success in connecting advances in geological hazards research with societal needs. He is the founder of the non-profit organization "In Harm's Way" that identifies areas of the world most vulnerable to natural disasters and helps community-based organizations in these areas access and communicate risk of natural hazards, and implement effective disaster risk-reduction strategies that have saved thousands of lives. See ***inharmswayhelp.org.***

BALLROOM B-C

SESSION I — **RADIATION EFFECTS IN DEVICES AND INTEGRATED CIRCUITS**

9:30 AM — SESSION INTRODUCTION

Chair: Enxia Zhang, Vanderbilt University

I-1 9:35 AM — **Cryogenic Total-Ionizing-Dose Response of 4th-Generation SiGe HBTs using 1-MeV Electrons for Europa-Surface Applications**

J. Teng[1], G. Tzintzarov[1], D. Nergui[1], J. Heimerl[1], Y. Mensah[1], J. Moody[1], D. Thorbourn[2], L. Del Castillo[2], L. Scheick[2], M. Mojarradi[2], B. Blalock[3], J. Cressler[1]

1. Georgia Institute of Technology, USA

2. Jet Propulsion Laboratory, USA

3. University of Tennessee Knoxville, USA

SiGe HBTs are exposed to 1-MeV electrons to 5 Mrad(Si) at 300, 200, and 115 K. Improved TID tolerance is exhibited at lower temperatures, and the physical mechanisms behind this improved tolerance are explored.

I-2 9:50 AM — **Layout Dependence of Total Ionizing Dose Effects on 12-nm Bulk FinFET Digital Structures**

T. Wallace[1], M. Spear[1], A. Privat[2], J. Neuendank[1], G. Irumva[1], D. Wilson[1], I. Sanchez Esqueda[1], H. Barnaby[2], M. Turowski[3], E. Mikkola[3], D. Hughart[4], M. Marinella[4], R. Von Niederhausern[5]

1. Arizona State University, USA

2. ASU, USA

3. Alphacore Inc., USA

4. Sandia National Laboratories, USA

5. Spacecraft Component Branch, Air Force Research Lab, USA

This summary reports on layout dependent TID susceptibility in a commercial 12nm FinFET technology. While current scales to drive strength prior to irradiation, after exposure, layout location becomes the dominant factor in TID response.

I-3 10:05 AM — **RF Performance and TID Hardness Trade-offs in Annular 45-nm RF SOI CMOS Devices**

B. Ringel[1], J. Teng[1], D. Nergui[1], M. Hosseinzadeh[1], K. Li[2], E. X. Zhang[2], D. M. Fleetwood[2], J. Cressler[1]

1. Georgia Institute of Technology, USA

2. Vanderbilt University, USA

The TID response of 45-nm annular RF SOI nFETs is evaluated against standard layouts. RF performance and TID susceptibility trade-offs are demonstrated. TCAD is used to isolate critical oxides and damage mechanisms in annular layouts.

10:20 AM – 10:50 AM — BREAK

NORTH & EAST PRE-FUNCTION

BALLROOM B-C
SESSION I (cont'd)

I-4 10:50 AM

Total Ionizing Dose Effects in FDSOI SRAM- Based XNOR IMC Synaptic Array

X. Han[1], M. Spear[1], J. Seo[1], D. Wilson[1], T. Wallace[1], O. Forman[1], J. Solano[1], M. Turowski[2], M. Marinella[1], H. Barnaby[1]

1. Arizona State University, USA

2. Alphacore, Inc, USA

SRAM-based XNOR in-memory computing has been proposed as a synaptic device for neural networks. The impact of total ionizing dose on the XNOR-and-accumulate computation (XAC) synaptic array is analyzed for a 22-nm FDSOI design.

I-5 11:05 AM

Total-Ionizing Dose Effects on 3D Sequentially-Integrated Ring Oscillators

S. Toguchi[1], E. X. Zhang[1], D. M. Fleetwood[1], R. D. Schrimpf[1], S. Moreau[2], P. Batude[2], L. Brunet[2], F. Andrieu[2], M. L. Alles[1]

1. Vanderbilt University, USA

2. CEA, LETI, France

Switched-bias during irradiation results in worst-case frequency decreases in ring oscillators built in FDSOI 3DSI technology due primarily to threshold-voltage shifts and transconductance degradation in the pull-up pMOSFETs.

I-6 11:20 AM

Effects of Geometry and Cycling on the Radiation Response of Charge-Trapping NAND Memory Devices with SiON Tunneling Oxide

J. Cao[1], E. X. Zhang[1], R. A. Reed[1], M. L. Alles[1], R. D. Schrimpf[1], D. M. Fleetwood[1], A. Arreghini[2], M. Rosmeulen[2], J. Bastos[2], G. Van den Bosch[2], D. Linten[2]

1. Vanderbilt University, USA

2. imec, Belgium

Effects of geometry and cycling are evaluated for charge-trapping NAND memory devices with SiON tunneling layers. Scaling to smaller dimensions enhances programmability, endurance, and radiation tolerance. Excellent endurance is demonstrated before and after irradiation.

I-7 11:35 AM

Effect of Total Ionizing Dose on Low-Power Artificial Intelligence Edge Processing Application-Specific Integrated Circuits for Space-Based Applications

M. Casey[1], J. Goodwill[1], E. Wyrwas[1], S. Stansberry[2], R. Austin[1], M. Carts[1], N. Gorius[3], C. Wilson[1], S. Aslam[1], J. Pellish[1]

1. NASA GSFC, USA

2. SSAI, USA

3. Catholic University of America, USA

The effects of total ionizing dose on two artificial intelligence application-specific integrated circuits are examined. Some post-irradiation failure analysis has been conducted to identify the source of the failures.

POSTER PAPERS

PI-1 TID Responses of Floating Body and Body-Contacted 45-nm PDSOI NMOS Transistors

A. Butterfield[1], M. Hu[1], E. X. Zhang[1], S. Vibbert[1], A. Watkins[1], J. Damico[1], B. Fahrenkrug[1], D. Ball[1], T. Haeffner[1], J. Kauppila[1], L. Massengill[1]

1. Vanderbilt University, USA

Measurements show transistors fabricated in a current 45-nm PDSOI process are resistant to ionizing radiation effects through 300 krad(SiO_2). Additionally, body contacted devices show a greater resistance to TID-induced degradation than comparable floating body devices.

PI-2 Total Ionizing Dose Effects on SRAM Power-up State

U. Surendranathan[1], H. Wilson[1], A. Milenkovic[1], B. Ray[1]

1. The University of Alabama in Huntsville, USA

The power-up state of commercial SRAM chips is significantly altered after irradiation, preventing its use for generating SRAM-PUFs in radiation-prone environments. The SRAM-PUF bit error rate increases monotonically with TID, exceeding 15% after 100 krad(Si).

PI-3 Predictive Study of the Performance Characteristics Degradation of Optocouplers Combining TID-DD Effects with Gamma and Proton Irradiation

P. Martin-Holgado[1], A. Romero-Maestre[1], J. De-Martin-Hernandez[2], J. Ramirez-Garcia[2], J. Gonzalez-Lujan[2], A. Ricca-Soaje[2], M. Sacristan Barbero[3], R. Ferraro[4], R. Garcia[5], M. Dominguez[6], Y. Morilla[1]

1. Centro Nacional de Aceleradores, Spain

2. Alter Technology, Spain

3. CIEMAT - CERN, Switzerland

4. CERN, France

5. CERN, Switzerland

6. ALTER, Spain

Optocouplers are crucial components in harsh environments, and therefore a prediction of their degradation due to radiation is highly demanded. This work shows a successful predictive tool for the CTR parameter based on archival data.

11:50 AM END OF CONFERENCE