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<th>Time</th>
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<tr>
<td>08:00</td>
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<td>09:00</td>
<td>Introduction</td>
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<td>Invited talk</td>
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<td>Session G Radiation Hardness Assurance</td>
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<td>11:00</td>
<td>Short Course Part II</td>
<td>Session C Single Event Effects:</td>
<td>Session B Radiation Effects on Devices &amp; ICs</td>
<td>Session D Single Event Effects: Devices &amp; ICs</td>
<td>10:50 Break</td>
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<td>Session F Hardening Techniques</td>
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<td>13:30</td>
<td>Short Course Part III</td>
<td>Session A Basic Mechanisms of Radiation Effects</td>
<td>Session I Facilities and Dosimetry</td>
<td>Session F Hardening Techniques</td>
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<td>End of Conference</td>
<td>18:30 30th Anniversary Gala Dinner</td>
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<td>17:10</td>
<td>Short Course Exam</td>
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<td>17:40</td>
<td>Industrial Exhibit Reception</td>
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<td>20:00</td>
<td>30th Anniversary Gala Dinner</td>
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9:00  
**Short Course Introduction**  
Short Course Chair: Frédéric Wrobel, University of Montpellier

**Prepare for the next decade!**  
This short course is intended for beginners as well as experts in the field. Basic and main concepts will be presented before focusing on various effects and technologies that are, and will be in the next decade, at play. It will cover displacement damage and ionizing dose effects for both silicon devices and emerging technologies. The issue of low energy protons for single event effects will be also addressed for space and high altitude environments. In addition, a talk on the complex challenges of mitigation techniques in FPGAs will be given. Finally, RHA strategies for aerospace systems will be presented.
Part I
09:10

OVERVIEW OF THE MAIN CONCEPTS OF RADIATION EFFECTS AND THEIR EVOLUTION OVER THE 30 YEARS OF RADECS CONFERENCES
Philippe Paillet, CEA

Philippe Paillet (M’97–SM’04–F’18) received his Master’s degree in Electrical Engineering from the Université Aix-Marseille I, France, in 1989 and his PhD degree in Electrical Engineering from the Université Montpellier II, France, in 1995. He joined the Commissariat à l’Energie Atomique (CEA) in Arpajon, France in 1995, and is now a CEA International Expert. Philippe has been involved in numerous programs developing radiation-hardened electronic and optoelectronic technologies, characterizing the physical mechanisms responsible for radiation response of components and ICs, modeling the effects of radiation in MOS technologies and creation of radiation-induced defects, and developing hardness assurance approaches. Philippe has authored or co-authored more than 200 publications, articles, short courses and book chapters, including three Best Papers at RADECS, two Meritorious Paper Awards at NSREC, one Best Paper Award at HEART, and five Outstanding Paper Awards at NSREC. He is currently serving as Vice-president of the RADECS Association and RADECS Liaison to the IEEE Radiation Effects Steering Group.

Abstract - An overview of the main concepts of radiation effects in electronic and optoelectronic devices and circuits will be provided. These main effects include both destructive and non-destructive events, and the underlying degradation mechanisms will be briefly introduced. Depending on the type of incoming particle (photon, proton, neutron, heavy ion) and the target technology or device, non-destructive effects can range from transient perturbation of electrical or optical parameters (Single-Event Upsets, Single Event Transients, photocurrents, etc…) to permanent degradation (Total Ionizing Dose induced charge trapping in insulators, Displacement Damage Dose in semiconductor materials). As a celebration of the 30-years of RADECS conferences, these main concepts will be presented with an emphasis on the historical perspective, and of the attention they drew at the conference since 1989.

Contents

- Total Ionizing Dose Effects in insulators
  Charge trapping; Effects on elementary device response ($V_{th}$ shifts, Device Leakage, etc...); Evolution with scaling
- Displacement Damage in semiconductor bulk
  Concepts of DDD and NIEL; main effects; and Simulation of displacement cascade generation and anneal
- Single-Event Effects in devices and ICs
  Destructive and non-destructive events; Charge generation and collection; Impact on device operations; Influence of scaling

10:25 Break
Abstract - This course will present a brief overview of total-ionizing-dose (TID) effects, and illustrate how 1/f noise measurements can provide significant insights into the responses of MOS devices and GaN-based HEMTs, with a focus on emerging technologies. Noise measurements are especially helpful when coupled with current-voltage and/or charge-pumping measurements, and/or first-principles theory calculations. Border traps are near-interfacial oxide traps that exchange charge with the underlying silicon on the time scales of measurements; their effects have become increasingly important for highly-scaled MOS devices. 1/f noise is quite sensitive to border traps in these devices. In GaN-based HEMTs, 1/f noise is sensitive to both total-ionizing-dose and displacement-damage effects. Examples will also be shown for SiC-based MOSFETs and other emerging MOS technologies (e.g., graphene, black phosphorus, MoS$_2$).

Contents

- TID in Isolation Oxides
  - Leakage, $V_n$ shifts
- Oxide and Border Traps
  - Effects on TID Response, Microstructure
- Low-frequency noise
  - Background, Measurements, Carrier Number Fluctuation Model, Defect Microstructure, Kinetics – Dutta-Horn Model, Illustrative Examples

12:00 Short Course Lunch
Kenneth P. Rodbell is a Principal Research Staff Member and presently manages a Materials Research Group at the IBM Thomas J. Watson Research Center in Yorktown Heights, NY. He received his B.S. (1982), M.S. (1983) and Ph.D. (1986) in Materials Science and Engineering, with a minor in statistics, from Rensselaer Polytechnic Institute, where he was a recipient of an IBM Research Fellowship for his graduate work. His technical interests have focused on Si based electronic materials, including thin film metallurgy, crystallographic texture, electromigration, and radiation induced soft errors in semiconductor devices (including the first definitive paper characterizing low energy proton induced fails in 65 nm SOI and the use of stacked latches to reduce SER in 32 nm SOI). He has co-authored more than 80 issued U.S. patents and was one of a team recognized as the New York State 2006 Inventor of the Year for a Cu plating technology patent.

**Abstract** - Upsets due to direct ionization from protons were first predicted in 1988 and then experimentally realized in 2007 for both low energy protons (1 MeV) and neutrons (1 – 10 MeV). For terrestrial applications, secondary - low energy protons, generated during collision events, may cause upsets, especially in cells further away from the initial strike location than their heavier spallation-fragment cousins. However, in space and high altitude environments, this direct ionization mechanism may be more important due to the large flux of primary high energy protons impinging on nearby spacecraft (and local device) shielding. In this short course a brief review of the relevant literature will be followed by a discussion of the sensitivity to direct ionization of typical CMOS devices. It will be shown that a significant number of low energy protons are generated, as a result of cosmic radiation spallation events, and suggests that track structures and exact device hit locations need to be understood and effectively modeled, especially for modern devices. Finally, the rate of multiple cell upsets, and hence multiple bit upsets, in these environments will be explored, with possible mitigation techniques discussed.

**Contents**
- SOI versus Bulk
- Proton direct ionization (PDI)
- Angle of incidence, SOI and MBUs
- LEP SEUs and reliability testing
- Elastic scattering
Abstract - FPGAs are increasingly being used to implement digital systems because of their versatility, performance per watt and NRE cost reduction. Today they are regularly found in space equipment. At the ground level, they are entering the high-performance computing market and are expected to be massively deployed in data centers, where neutron sensitivity may be a concern. Furthermore, modern FPGAs are complex devices that include a wide variety of resources and interfaces, and their complexity is expected to increase in the future. As a result, radiation hardness assurance is challenging. This course will provide an up-to-date overview of radiation effects on major FPGA technologies, sensitivity evaluation methods and mitigation techniques and tools. Available space-grade devices will be presented and compared with COTS FPGAs, which are also making their way with the aid of user-implemented mitigation techniques.

Contents
- Introduction to FPGAs
- Radiation effects and mitigation techniques in FPGAs
- Radiation-hardened FPGAs
- Sensitivity evaluation
- Mitigation techniques for COTS FPGAs
Part V  
16:00  
RADIATION HARDNESS ASSURANCE: EVOLVING FOR NEW SPACE  
Michael Campola, NASA/GSFC, Jonathan Pellish, NASA

Michael Campola is employed at the Goddard Space Flight Center (GSFC) as the National Aeronautics and Space Administration’s Radiation Effects and Analysis Group (REAG) Leader. Michael received a B.S. degree in Engineering Physics from Embry-Riddle Aeronautical University, and the M.S. degree in Electrical Engineering from Arizona State University. Michael joined the Flight Data Systems and Radiation Effects Branch at NASA Goddard Spaceflight Center in 2007, working on flight projects and research to capture system level radiation response. He has worked on programs and projects such as Magnetospheric MultiScale (MMS) Mission, Landsat 8, ICESat-2, and Transiting Exoplanet Survey Satellite (TESS), which are currently operational on orbit. He is a member of the Institute for Electrical and Electronics Engineers.

Dr. Jonathan “Jonny” Pellish is employed at the Goddard Space Flight Center (GSFC) as the National Aeronautics and Space Administration’s Electrical, Electronic, and Electromechanical (EEE) Parts Manager, responsible for workforce stewardship and coordinating Agency-wide discipline technical activities in the EEE parts and radiation effects engineering communities. Jonny is also the deputy manager for the NASA Electronic Parts and Packaging (NEPP) Program, which is operated by GSFC for the NASA Office of Safety and Mission Assurance. Dr. Pellish received the B.S. degree in physics from Vanderbilt University in 2004, and the M.S. and Ph.D. degrees in electrical engineering from Vanderbilt University in 2006 and 2008. From 2007–2008 Jonny held an IBM Ph.D. Fellowship, which included a co-op position at the IBM Austin Research Laboratory. Jonny has authored or co-authored over 60 refereed publications in addition to numerous conference and workshop presentations. He is a member of the American Institute of Aeronautics and Astronautics and the Institute for Electrical and Electronics Engineers.

Abstract - Dr. Jonathan Pellish, NASA Electronic Parts Manager, and Mr. Michael Campola, NASA Goddard Space Flight Center (GSFC), will present radiation hardness assurance (RHA) strategies that engineers and scientists can apply to a wide range of aerospace systems, with a focus on how to manage aggressive system scaling for smaller platforms. During the past decade, numerous small satellites have been launched into space, with dramatically expanded dependence on advanced commercial-off-the-shelf (COTS) technologies and systems required for mission success. While the radiation effects vulnerabilities of small satellites are the same as those of their larger, traditional relatives, revised approaches are needed for risk management because of differences in technical requirements and programmatic resources. While moving to COTS components and systems may reduce direct costs and procurement lead times, it undermines many cost-reduction strategies used for conventional RHA. Limited resources are accompanied by a lack of radiation testing and analysis, which can pose significant risks—or worse, be neglected altogether. Small satellites have benefited from short mission durations in low Earth orbits with respect to their radiation response, but as mission objectives grow and become reliant on advanced technologies operating for longer and in harsher environments, requirements need to reflect the changing scope without hindering developers that provide new capabilities.

Contents

- New Space and SmallSat Considerations
- The Natural Space Radiation Environment Hazard
- Radiation Effects on Micro-Electronics
- Hardness Assurance, as a Discipline, with its Challenges
  - New Technologies
  - New Architectures
  - Unbound Risks
- Building Smart Requirements
- Risk Acceptance and Guidance

17:00  
End of Short Course
17:10  **SHORT COURSE EXAM** (30 min)

At the end of the short course, there will be a short quiz for attendees who want to evaluate their understanding about the talks. Attendees who pass the exam will receive a certificate.

To participate, please note that you need to:

- Be registered to the short course
- Have your own laptop with internet connection (Wi-Fi provided by conference)
- Register to the IWantECTS website prior to the conference
TECHNICAL PROGRAM TUESDAY

9:00  
Conference Opening Remarks

9:30  
Technical Program Introduction  
Technical Program Chair: Françoise Bezerra (CNES)

Session C  
SINGLE EVENT EFFECTS: MECHANISMS & MODELLING
09:40  
Chairs: Heather Quinn (LANL) & Magali Haussy (Thales Alenia Space)

C-1  
Angular Sensitivity of Neutron-Induced Single-Event Upsets in 12-nm FinFET SRAMs with Comparison to 20-nm Planar SRAMs
09:45  
T. Kato¹, H. Matsuyama¹  
¹. Socionext Inc., Japan

Neutron-induced single-event upsets are studied in 12-nm FinFET SRAMs with varying incidence angle. Comparison with 20-nm planar SRAMs reveals different angular sensitivities of multiple-cell upsets. Parasitic bipolar effects are likely a key mechanism underlying this.

C-2  
The Pion Single Event Effect Resonance and its Impact in an Accelerator Environment
10:00  
A. Coronetti¹, R. Garcia Alia², M. Cecchetto³, W. Hajdas², D. Soderstrom³, A. Javanainen³, F. Saigne⁴  
¹. CERN, France  
². PSI, Switzerland  
³. Jyvaskylan Yliopisto, Finland  
⁴. Universite de Montpellier, France

The pion SEU and SEL cross-section is experimentally investigated and is found to be higher than that of protons above 100 MeV (resonance). Numerical simulations are proposed to study the different nuclear interactions involved.

C-3  
Cross-Calibration of Various SEE Test Methods Including Pulsed X-rays and Application to SEL and SEU
10:15  
G. Augustin¹, M. Mauguet¹, N. Andrianjohany¹, N. Chatry¹, F. Bezerra², E. Capria³, M. Sander³, K. Voss⁴  
¹. TRAD, France  
². CNES, France  
³. ESRF, France  
⁴. GSI, Germany

Correlations are established between heavy ions, X-rays and simulations using charge measurements on a photodiode. These results are then used to performed comparative SEU and SEL tests on integrated circuits.

10:30  
Break

C-4  
Heavy Ion Nuclear Reaction Impact on SEE testing: from Standard to Ultra-High Energies
11:00  
V. Wyrwoll¹, R. Garcia Alia², K. Roed³, P. Fernandez Martinez², M. Kastriotou², M. Cecchetto², N. Kerboub², M. Tali², F. Cerutti²  
¹. CERN/University of Oslo, Switzerland  
². CERN, Switzerland  
³. University of Oslo, Norway  
⁴. CERN/ESA/University of Jyvaskyla, Switzerland

Monte Carlo (MC) simulations and experimental data of high energy protons and heavy ions in a broad energy range have been studied focusing on the sub-LET threshold region for Single Event Latch-up (SEL) cross section.
**C-5**  
**11:15**  
Pulsed Laser-Induced Single-Event Transients in InGaAs FinFETs with Sub-10-nm Fin Widths  
K. Li¹, E. Zhang², S. Bonaldo², A. Sternberg³, J. Kozub¹, M. Reaz¹, L. Ryder¹, K. Ryder¹, H. Gong¹, S. Weiss¹, R. Weller¹, A. Vardi³, J. Alamo³, R. Reed¹, D. Fleetwood¹, R. Schrimpf¹  
¹. Vanderbilt University, USA  
². University of Padova, Italy  
³. Massachusetts Institute of Technology, USA  
The single-event transient response and charge collection mechanisms are investigated for InGaAs FinFETs on InP with sub-10-nm fin widths. The dependences on fin width, VDS, VGS, and laser energy are consistent with wider-fin devices.

**C-6**  
**11:30**  
Rad-Ray: A new Simulation Tool for the Analysis of Heavy Ions-induced SETs on ICs  
L. Sterpone¹, F. Luoni², S. Azimi¹, B. Du¹  
¹. Politecnico di Torino, Italy  
². GSI, Germany  
We present Rad-Ray, a tool for simulating the passage of heavy ions particles through the silicon matter of modern Integrated Circuits and generating the transient voltage pulse response. Heavy ions radiation campaigns demonstrated comparable results.

**C-7**  
**11:45**  
Impact of electrical stress and neutron irradiation on reliability of Silicon Carbide power MOSFETs  
K. Niskanen¹, A. Touboul¹, R. Germanicus², A. Michez¹, A. Javanainen³, F. Wrobel¹, J. Boch¹, V. Pouget¹, F. Saigne¹  
¹. IES, University of Montpellier, France  
². CRISMAT LAMIPS, France  
³. RADEF, Finland  
Effects of electrical stress and neutron irradiation to Single Event Burnout (SEB) sensitivity and breakdown voltage degradation of silicon carbide power MOSFETs was studied. Different SEB behavior between stressed and fresh devices was observed.

**C-8**  
**12:00**  
Single-Event Transient Space Characterization in 28nm SOI Technologies and below  
C. Lecat¹, F. Abouzeid¹, V. Malherbe¹, J. Daveau¹, G. Gasiot¹, P. Roche¹, J. Autran²  
¹. STMicroelectronics, France  
². IM2NP, France  
A Single-Event Transient study was performed on two FDSOI technology nodes, embedding a novel characterization structure and with the help of Monte-Carlo simulations.

**C-9**  
**12:15**  
Single Event Latchup Cross Section Calculation from TCAD Simulations - Effect of the Doping Profiles and Anode to Cathode Spacing  
S. Guagliardo¹, F. Wrobel², Y. Aguiar³, J. Autran³, P. Leroux³, F. Saigné¹, V. Pouget¹, A. Touboul³  
¹. IES, University of Montpellier, France  
². Aix-Marseille University, France  
³. Leuven University, Belgium  
In this paper SEL cross sections were calculated from TCAD simulations varying doping profiles and anode-to-cathode spacing values. We found that doping profiles variation has a stronger impact on SEL sensitivity then variation of spacing.

**POSTER PAPERS**

**PC-1**  
J. Hales¹, A. Khachatrian¹, J. Warner¹, S. Buchner¹, D. Mc Morrow¹  
¹. U.S. Naval Research Laboratory, USA  
Quantitative pulsed-laser testing using two-photon absorption is challenging due to its complicated dependence on laser pulse parameters. This work focuses on an accurate, yet simplified, approach for enabling such quantitative testing.
Atmospheric Neutron Radiation Response of III-V Binary Compound Semiconductors

J. Autran¹, D. Munteanu²
1. Aix-Marseille University, France
2. CNRS, France

This work examines the radiation response of III-V binary compound semiconductors subjected to high energy atmospheric neutrons. Production of neutron-induced secondary products and implications for single event effects are carefully analyzed and discussed.

Heavy-Ion Microbeam Studies of Radiation-Sensitive Regions of SiC VD-MOSFETs

C. Martinella¹, T. Ziemann², K. Voss³, R. Garciaalia⁴, Y. Kadi⁴, U. Grossner², A. Javanainen⁵
1. CERN, University of Jyväskylä, Switzerland
2. APS - ETH Zurich, Switzerland
3. Material Research Department at GSI, Germany
4. CERN, Switzerland
5. RADEF, Finland

Micro-probe experiments allow a micrometer-accurate localization of the radiation-sensitive regions in SiC VD-MOSFETs, providing useful information for the comprehension of basic phenomena of Single Event Effects in SiC commercial technologies.

Behavior of Damaged Sites Introduced by SEGR in Silicon Carbide Power MOSFETs

Y. Nakada¹, S. Kuboyama², E. Mizuta³, H. Shindou³, A. Takeyama³, T. Ohshima²
1. JAXA, Japan
2. National Institutes for Quantum and Radiological Science and Technology, Japan

It was found that the behavior of damage sites introduced by SEGR in SiC vertical power MOSFETs were essentially different from the one observed in corresponding Si devices, although the electrical behavior was similarly modeled.

Comparative Analysis of Upset-Multiplicity Occurrences due to Flash X-rays and Pulsed Neutrons in Commercial SRAMs

C. Qi², W. Chen², Y. Wang¹, G. Wang², R. Li², X. Bai², X. Jin²
1. Peking University, China
2. Northwest Institute of Nuclear Technology, China

Upset bursts in 65-nanometer commercial SRAMs due to flash X-rays and pulsed neutrons are successfully distinguished from the experimental point of view, by an approach of analyzing upset-multiplicity occurrences.

SEU Prediction for Very Integrated Circuits based on Advanced Physical Considerations

N. Rostand¹, G. Hubert¹, S. Martinie²
1. ONERA, France
2. CEA/LETI, France

Charge deposit morphology and advanced physical features are part of the new challenges in SET modelling for SEU prediction. In this paper, we address them with a novel simulation flow.

Standard Verification Flow Compatible Layout-Aware Fault Injection Technique for Single Event Effects Tolerant ASIC Design

I. Danilov¹, A. Khazanova¹, A. Balbekov¹, M. Gorbunov¹
1. Scientific Research Institute of System Analysis, Russian Academy of Sciences (SRISA), Russian Federation

We propose a layout-aware fault injection technique for Single Event tolerant integrated circuits design. Being fully compatible with standard verification flow, the proposed technique is applied to AES crypto cores implemented with TMR.
PC-8  Engineering TID modeling for the SEE and performances evaluations of integrated CMOS circuits at cryogenic temperatures
L. Artola¹, S. Ducret¹, G. Hubert¹
1. ONERA, France
2. Sofradir, France
This paper presents a TID modeling approach based on Cobalt60 irradiations of CMOS transistors. The TID models were developed for the investigation of logic and sequential gates performances (SEE and delay) at cryogenic temperatures.

PC-9  Analysis of Radiation-induced SETs in 3D VLSI Face-to-Back LUTs
L. Sterpone¹, L. Bozzoli¹, C. De sio¹, B. Du¹, S. Azimi¹
1. Politecnico di Torino, Italy
In this work we propose a new method for evaluating the radiation-induced Single Even Transients on 3D FPGA’s Look-Up Table. Experimental analysis performed on a 15-nm 3D LUT provide effective static and dynamic error rate.

PC-10  A Statistical Method for MCU Extraction Without Layout Information
X. Wang¹, L. Ding¹, Y. Luo¹, W. Chen¹, F. Zhang¹, X. Guo¹
1. Northwest Institute of Nuclear Technology, China
A statistical method was proposed to extract physical LSBs and MCUs from SEU data without layout information. Application of the method on a SRAM demonstrated its effectiveness to extract the shapes and rates of MCUs.

PC-11  New Approach of Single Event Latchup Modeling Based on TCAD Simulations and Design of Experiment Analysis
D. Truyen¹, L. Montagner¹
1. MICROCHIP, France
This work presents a predictive SEL modeling based on physical simulations and DOE analysis. The model is built from layout and process inputs and evaluates SEL risk by estimating the LET threshold and holding voltage.

PC-12  A mathematical model to predict microprocessors fault tolerance under proton and neutron irradiation
L. Reyneri¹, A. Serrano-cases², Y. Morilla³, S. Cuenca-asensi², A. Martínez-Álvarez²
1. Politecnico di Torino, Italy
2. University of Alicante, Spain
3. Centro Nacional de Aceleradores (Universidad de Sevilla, CSIC, JAmes), Spain
Mathematical model to predict microprocessors fault tolerance under accelerated radiation campaigns. Model built using radiation data from CNA’s Cyclotron (Spain) and LANSCE (USA). An ARM-SoC device were used to assess the model over different applications.

12:30  Lunch

Session A  BASIC MECHANISMS OF RADIATION EFFECTS
14:00  Chairs: Christophe Inguimbert (ONERA) & Yago Gonzalez Velo (ASU)
TECHNICAL PROGRAM TUESDAY

A-1  TID Mechanisms and Low-frequency Noise in 28 nm MOSFETs Irradiated to Ultra-high Doses  
14:05  
S. Bonaldo¹, S. Mattiazzo², C. Enz³, A. Baschirotto³, D. Fleetwood⁴, A. Paccagnella¹, S. Gerardin¹  
¹. University of Padova, Italy  
². EPFL - Ecole Polytechnique Fédérale de Lausanne, Switzerland  
³. University of Milano Bicocca, Italy  
⁴. Vanderbilt University, USA  
TID mechanisms at ultra-high doses are investigated in 28 nm pMOSFETs and nMOSFETs through DC and low-frequency noise measurements. The TID sensitivity depends on channel-length, channel-width, and bias condition.

A-2  TID Response of PMOS Bulk Si FinFETs: Bias, Fin Width and Orientation Dependence  
14:20  
Z. Ren¹, X. An¹, G. Li¹, G. Chen¹, M. Li¹, G. Yu², Q. Guo², X. Zhang¹, R. Huang¹  
¹. Peking University, China  
². Xinjiang Technical Institute of Physics and Chemistry, Chinese Academy of Sciences, China  
The TID response of PMOS bulk Si FinFETs with two fin widths and two orientation is experimentally investigated under four irradiation bias conditions. The bias and orientation dependence of TID response are demonstrated firstly.

A-3  The Sensitive Region of Displacement Damage in LPNP induced by Various Charged Particles  
14:35  
X. Li¹, J. Yang¹, P. Li¹, X. Sun¹, L. Dong¹  
¹. Harbin Institute of Technology, China  
The sensitive region of displacement damage in LPNP induced by various charged particles was investigated. Experimental results show that the displacement damage can be equivalent based on the radiation sensitive region of Si/SiO₂ interface.

POSTER PAPERS

PA-1  Simulation of Single Particle Displacement Damage in Si₁₋ₓGex alloys – Interaction of Primary Particles with the Material and Generation of the Damage Structure  
T. Jarrin¹, A. Jay², M. Raine¹, N. Mousseau³, A. Hémeryck⁴, N. Richard¹  
¹. CEA, DAM, DIF, France  
². ISAE–SUPAERO, Université de Toulouse, France  
³. Université de Montréal, Canada  
⁴. LAAS/CNRS, France  
Primary interaction simulation with neutrons and collision cascades starting with Si and Ge Primary Knock-On Atoms are performed on Si₁₋ₓGex alloys using Monte-Carlo (MC) and Molecular dynamics (MD) codes.

PA-2  Comparison of X-Ray and Proton Irradiation Effects on the Characteristics of InGaN/GaN Multiple Quantum Wells Light Emitting Diodes  
L. Wang¹, B. Li², X. Zhang³, N. Liu², Q. Yuan³, N. Liu⁴, M. Liu¹, B. Li¹, J. Gao¹, Y. Huang¹, J. Yang⁵, X. Li⁵, J. Luo¹, Z. Han¹, X. Liu¹  
¹. Key Laboratory of Silicon Device Technology, Institute of Microelectronics, Chinese Academy of Sciences, China  
². Guangdong Institute of Semiconductor Industrial Technology, Guangzhou, Guangdong 510650, People’s Republic of China, China  
³. Institute of High Energy Physics, Chinese Academy of Sciences, Beijing 100049, People’s Republic of China, China  
⁴. Institute of Semiconductors, Chinese Academy of Sciences, Beijing 100083, People’s Republic of China, China  
⁵. Harbin Institute of Technology, Harbin city, People’s Republic of China, China  
Different from proton, X-ray irradiation increased the external quantum efficiency of GaN-LEDs from original 56.7% to 61.8%. ABC model fittings revealed the Shockley-Read-Hall and radiative recombination rates were both found to be improved after irradiation.
Effect of Low Temperatures Irradiation on NPN Bipolar Junction Transistors
J. Dardié¹, J. Boch², A. Michez², C. Guasch², S. Bouisri², F. Saigné², F. Bezerra³, J. Favre⁴
1. TMI-Orion & IES, France
2. IES, University of Montpellier, France
3. CNES, France
4. TMI-Orion, France
The effect of dose on NPN bipolar junction transistors is investigated for irradiation performed at low temperatures. Degradation of forward-Gummel curves and current gain is shown and discussed in terms of physical mechanisms.

Impact of High-Energy Proton Irradiation on MoS2 Films and Its Field Effect Transistors
H. Zhu¹, L. Wang¹, J. Shi¹, X. Huang¹, Z. Zheng¹, G. Xiong¹, B. Li¹, J. Luo¹, Z. Han¹, X. Liu¹
1. Institute of Microelectronics, Chinese Academy of Sciences, China
Sulfur vacancies introduced by proton irradiation in MoS2 film cause multilayer MoS2 to be decoupled, resulting in a indirect-to-direct bandgap transition. Unlike the irradiation-introduced interface states, sulfur vacancies can improve the performance of MoS2 devices.

Proton Effect Test Compare to ZnO Thin Film Transistors with Different Active Layer Structures
Y. Kim¹, J. Jeong², G. Lee²
1. KOMAC, Korea, Republic of
2. Chungnam National University, Korea, Republic of
We investigated the ZnO TFTs with different structures of active layer after high dose proton irradiation. For the ZnO NRs, an anomalous hump was disappeared, and their performance was dramatically improved than the ZnO film.

Mutual Influence Mechanism of Displacement Damage and Total Ionizing Dose Effect of Lateral PNP Bipolar Transistors
Y. Liu³, C. He³, W. Chen³, C. Wang³, X. Jin³, X. Bai³, J. Li³
1. Northwest Institute of Nuclear Technology; Xi’an Jiaotong University, China
2. Xi’an Jiaotong University, China
3. Northwest Institute of Nuclear Technology, China
The interaction between DD effect and TID effect of GCLPNP transistors is studied by neutron and gamma irradiation experiments with different sequences. The mechanisms of the effects are explored by charge separation methodology on GCLPNPs.

Estimation of Residual Radionuclides Induced Electron Radiation Damage in SiC after HANARO Neutron Irradiation
K. Lee¹, B. Park¹
1. Korea Atomic Energy Research Institute, Korea, Republic of
The DPA value for SiC is calculated by using PHITS code to estimate the electron radiation damage, based on the radioactivity data of neutron induced residual radionuclides in SiC after irradiation with HANARO neutrons.

Modeling Radiation Damage to Pixel Sensors in the ATLAS Detector
J. Zahreddine¹
1. Laboratoire de Physique Nucleaire et de Hautes Energies (LPNHE), Sorbonne University, Paris-Diderot Sorbonne Paris Cite, CNRS/IN2P3, France
A model of pixel digitization is presented including radiation damage effects to the ATLAS pixel sensors. Thorough description of setup, and predictions for basic pixel cluster properties, alongside early studies with LHC Run-2 proton-proton collision data are presented.
A Direct Evidence of the Annealing Effect of Ionization Damage on Displacement Damage in NPN Transistors
J. Yang¹, G. Lv¹, L. Dong¹, X. Li¹
1. Harbin Institute of Technology, China

In this paper, based on the sequential irradiation of 40 MeV Si ions and Co-60 gamma ray, a direct evidence of the annealing effect of ionization damage on displacement damage in NPN transistors is investigated.

Session E  PHOTONICS, OPTOELECTRONICS & SENSORS
14:50 Chairs: Matthieu Beaumel (SODERN) & Jeffrey Warner (NRL)

E-1  Combined temperature and radiation effects on radiation sensitive single-mode optical fibers
14:55 C. Campanella¹, A. Morana¹, S. Girard², A. Guttilla³, F. Mady³, M. Benabdesselam³, H. Desjonqueres⁴, C. Monsanglant-Louvet⁴, C. Ballard⁵, E. Marin⁶, Y. Ouerdane⁷, A. Boukenter⁸, S. Lesoille⁹
1. Laboratoire Hubert Curien, France
2. Université de Saint Etienne, France
3. Université de Nice, France
4. Institut de Radioprotection et de Sûreté Nucléaire, France
5. Agence Nationale pour la gestion des Déchets Radioactifs, France

We analyzed the simultaneous response to radiation and temperature exposure of radiation-sensitive optical fibers in the framework of the CERTYF project in order to build a predictive model based on intrinsic and extrinsic optical parameters.

E-2  Radiation-response of Fiber Bragg Gratings at Low Temperatures
15:10 A. Morana¹, S. Girard¹, E. Marin¹, L. Lablonde², T. Robin³, M. Lancry⁴, A. Boukenter⁵, Y. Ouerdane¹
1. Université Jean Monnet, France
2. iXblue, France
3. iXblue, Finland
4. Institut de Chimie Moléculaire et des Matériaux d’Orsay, Université Paris Sud, France
5. Université Jean Monnet, France

The radiation-resistance of different types of gratings was investigated at -120°C up to the accumulated dose of 100 kGy(SiO2). The temperature sensitivity of these gratings was evaluated at low temperatures, before and after irradiation.

15:25 Break

E-3  Simulating charge deposition by cosmic rays inside astronomical imaging detectors
15:55 D. Lucsanyi¹, T. Prodhomme¹
1. ESA, ESTEC, Netherlands

Accurate and fast modelling of spurious images generated by solar and galactic cosmic rays in imaging detectors is critical for Space Astronomy missions. We present a novel cosmic ray model validated against test data.
We discuss the annealing effects and degradation on CMOS image sensors (CIS) after total ionizing doses of up to 1 MGy(SiO2), through the analysis of the CIS electronics behaviors and the dark current evolutions.

Displacement damage effects in InGaAs photodiodes produced by electrons, protons and neutrons irradiations

Different InGaAs photodiodes have been irradiated with electrons, protons, neutrons and gamma. The increase of the dark current has been analyzed and the damage factors have been compared with the NIEL scaling.

High Displacement Dose Effects in Radiation Hardened CMOS Image Sensors

MGy radiation tolerant CIS are exposed to neutron fluences beyond 10^14 cm^-2 and their performance characteristics are studied to evaluate the capability of this technology to be used in a high displacement damage dose environment.

Phosphorus Versus Arsenic: Role of the Photodiode Doping Implant in CMOS Image Sensor Dark Current and Random Telegraph Signal.

Proton irradiations on shallow-Arsenic and deep-Phosphorus photodiodes based CMOS Image Sensors have been performed. Results suggest that Phosphorus-based implant does not play a major role in radiation-induced dark current increase and RTS.

Combined effect of radiation and temperature: towards optical fibers suited to distributed sensing in extreme radiation environments

Combined effect of gamma-rays irradiation (1 to 10 MGy) and temperature (up to 250°C) is evaluated on RIA and strength of polyimide coated pure silica core single-mode fibers fabricated from MCVD and SPCVD deposition techniques.
**PE-2**

**Steady State X-ray radiation responses of Optical Fibers at Room and Liquid Nitrogen Temperatures**

A. Morana¹, V. De Michele¹, C. Campanella², J. Vidalot¹, A. Alessi¹, A. Boukenter¹, M. Cannas², Y. Ouerdane¹, P. Paillet³, N. Richard³, T. Robin⁴, S. Girard⁴

¹. Laboratoire Hubert Curien, France
². University of Palermo, Department of Physics and Chemistry - Emilio Segré, Italy
³. CEA, France
⁴. Oblue, France
⁵. Université de Saint Etienne, France

We characterize the response, under continuous X-ray irradiation, of fibers representative of the most common types of optical fibers, diversified by the composition. The on-line RIA spectra were recorded at room and liquid nitrogen temperatures.

**PE-3**

**X-ray irradiation response of antireflection coatings**

C. Muller¹, T. Allanche², A. Morana², P. Paillet³, T. Lépine², A. Boukenter², Y. Ouerdane², S. Girard⁴

¹. CEA, DIF / Laboratoire Hubert Curien, France
². Laboratoire Hubert Curien, France
³. CEA, France
⁴. Université de Saint Etienne, France

In the domain of imaging in harsh environments, antireflection coatings increase the flux on the sensor. We studied the radiation response of such coatings under X-rays at the MGy level and showed no significant effect.

**PE-4**

**Abnormal photoresponse properties of hybrid perovskite photodetector induced by proton beam irradiation**

G. Xiong¹, Z. Qin³, H. Zhu¹, S. Zhao³, L. Wang¹, B. Li¹, X. Zhang¹, Z. Zheng¹, J. Gao¹, J. Yang⁴, X. Li⁴, B. Li¹, Y. Huang¹, J. Luo¹, Z. Han¹, X. Liu¹

¹. Institute of Microelectronics of Chinese Academy of Science, China
². Key Laboratory of Luminescence and Optical Information, Ministry of Education, Institute of Optoelectronic Technology, Beijing Jiaotong University, China
³. Institute of Optoelectronic Technology, Beijing Jiaotong University, China
⁴. School of Materials Science and Engineering, Harbin Institute of Technology, China

Radiation effects on the electrical and optical properties of hybrid perovskite photodetectors were evaluated. An abnormal transient inverse current came out due to proton beam induced electron centers. Energy band model was established to reveal the mechanism.

**PE-5**

**Similarities between Heavy Ions and LASER tests in Back-Side Illuminated CMOS image sensor**

C. Virmontois¹, J. Belloir¹

¹. CNES, France

This paper focuses on the similarities between heavy ions and LASER tests to evaluate single event effect in back-side illuminated CMOS image sensor using last generation imaging process.

**PE-6**

**Several-Mrad(Si) total ionization dose effect on backside-illuminated CMOS image sensors**

X. Zhang¹, Y. Li², Q. Guo¹, L. Wen², J. Feng², L. Ma³, T. Wang¹, Y. Cai¹, Z. Wang¹, B. Liu¹

¹. Xinjiang Technical Institute of Physics and Chemistry, Chinese Academy of Sciences, China

Due to some novel oxide structures in BSI CISs, they may behave different degradation effects. Several-Mrad(Si) ionizing experiment has been carried out on BSI CIS along with parameter tests before and after the irradiation experiment.
Proton Irradiation Effects on the Static and Dynamic Characteristics of GaN-based Blue Light Emitting Diodes for Space Light Communication

L. Wang¹, B. Li¹, J. Wang², X. Guan³, X. Zhang³, N. Liu², Z. Gong², Z. Wei³, H. Zhu¹, N. Liu⁴, B. Li¹, J. Gao¹, Y. Huang¹, M. Liu¹, J. Yang³, X. Li³, J. Luo¹, Z. Han¹, X. Liu¹

1. Key Laboratory of Silicon Device Technology and Institute of Microelectronics, Chinese Academy of Sciences, China
2. Guangdong Institute of Semiconductor Industrial Technology, Guangdong Academy of Sciences, Guangzhou, China
3. Laboratory of Nanophotonic Functional Materials and Devices, Laboratory of Quantum Information Technology, South China Normal University, Guangzhou, China
4. Institute of Semiconductors, Chinese Academy of Sciences, Beijing, China
5. School of Materials Science and Engineering, Harbin Institute of Technology, Harbin, China

Although light-output power of GaN-LEDs decreased after proton irradiation, the 3dB bandwidth was improved beyond 16 times. Based on frequency response data, the competition between Shockley-Read-Hall and radiative recombination process was enhanced by proton irradiation.

17:10 End of Tuesday Sessions

18:30-21h30 Industrial Exhibit Reception
TECHNICAL PROGRAM WEDNESDAY

Invited Talk
MARS MISSIONS
08:30
S. Maurice, IRAP

Session B
RADIATION EFFECTS ON DEVICES & ICS
09:30
Chairs: Alain Michez (Université de Montpellier) & Hipolito Guzman (Universidad de Sevilla)

B-1
Total Dose Effects on Negative and Positive Low-Dropout Linear Regulators
09:35
A. Privat\textsuperscript{1}, P. Davis\textsuperscript{1}, H. Barnaby\textsuperscript{1}, P. Adell\textsuperscript{2}
\textsuperscript{1}. ASU, USA
\textsuperscript{2}. NASA JPL, USA
Total ionizing dose functional failure analysis on positive and negative voltage regulators is performed. Different failure mechanisms are observed that can be explained through electrical simulations. Experimental data and electrical simulations are provided.

B-2
Radiation-induced point- and cluster-related defects in epitaxial silicon pad diodes irradiated with different particle types and fluences
09:50
Y. Gurimskaya\textsuperscript{1}, I. Mateu\textsuperscript{1}, M. Moll\textsuperscript{2}, L. Makarenko\textsuperscript{2}, E. Fretwurst\textsuperscript{3}, I. Pintilie\textsuperscript{4}
\textsuperscript{1}. CERN, Switzerland
\textsuperscript{2}. Department of Applied Mathematics, Belarusian State University, Belarus
\textsuperscript{3}. University of Hamburg Institute for Experimental Physics, Germany
\textsuperscript{4}. National Institute of Material Physics, Romania
A consistent quantitative description of radiation-induced degradation on p-type Silicon detectors is conducted within CERN RD50 collaboration. Present contribution summarizes obtained results for epitaxial thin pad diodes irradiated with protons, neutrons and gamma rays.

B-3
Temperature Response on NPN and PNP Bipolar Junction Transistors after Total Ionizing Dose Irradiation Exposure
10:05
A. Privat\textsuperscript{1}, H. Barnaby\textsuperscript{1}, B. Tolleson\textsuperscript{1}, M. Kiraneswar\textsuperscript{1}, P. Adell\textsuperscript{2}
\textsuperscript{1}. ASU, USA
\textsuperscript{2}. NASA JPL, USA
A temperature-dependent analytical model for TID-induced excess base current in BJTs is proposed for implementation in SPICE circuit simulators. Model captures base current evolution with temperature after irradiation. Simulations show good correlation with experimental results.

B-4
Proton Irradiation Test on a Piezoelectric Actuator
10:20
P. Serrano gálvez\textsuperscript{1}, S. Solis paiva\textsuperscript{1}, E. Guillermain\textsuperscript{1}, M. Butcher\textsuperscript{1}, M. Di castro\textsuperscript{1}, A. Masi\textsuperscript{1}
\textsuperscript{1}. CERN, Switzerland
A Proton Irradiation Test up to 2MGy and 1.14e16 p/cm\textsuperscript{2} fluence on a piezoelectric actuator used for Crystal Collimation is presented. The results show an impedance increase of \&lt;25% and a free-stroke reduction of \&lt;25%.

10:35
Break
<table>
<thead>
<tr>
<th>Time</th>
<th>Title</th>
<th>Authors</th>
<th>Affiliations</th>
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| 11:05 | Effects of Total Ionizing Dose on Transient Radiation Upset sensitivity of 40-180nm SRAMs | J. Li\(^1\), R. Li\(^1\), W. Chen\(^1\), C. He\(^2\), G. Wang\(^3\), C. Qi\(^1\), Y. Liu\(^1\), X. Jin\(^1\), C. Wang\(^1\), X. Bai\(^1\) | 1. Northwest Institute of Nuclear Technology, China  
2. Xian Jiaotong University, China |
|       |                                                             | The synergistic effects of total ionizing dose on transient radiation upset sensitivity of SRAMs with three distinct technology nodes from sub-micrometer to nano-meter was investigated by using Co-60 gamma rays and pulsed X-ray. |
| 11:20 | DCR degradation probability in CMOS SPADs exposed to a non-monochromatic neutron source | L. Ratti\(^1\), P. Brogi\(^2\), G. Collazuol\(^3\), G. Dalla betta\(^4\), A. Ficorella\(^6\), P. Marrocchesi\(^2\), F. Morsani\(^5\), L. Pancheri\(^4\), G. Torilla\(^1\), C. Vacchi\(^1\) | 1. Università di Pavia, Italy  
2. Università di Siena, Italy  
3. Università di Padova, Italy  
4. Università di Trento, Italy  
5. INFN, Italy |
|       |                                                             | A model for the probability of neutron-induced DCR increase in CMOS SPADs fabricated in 180 nm and 150 nm technology is evaluated through comparison with experimental data obtained with a non-monochromatic source. |
| 11:35 | Highlight of Total Ionizing Dose Effects on a RF Front-end by means of Microwave Nonlinear Characterization | S. Jarrix\(^1\), L. Chusseau\(^1\), J. Raoult\(^1\), J. Boch\(^1\), T. Maraine\(^1\) | 1. IES, University of Montpellier, France |
|       |                                                             | The measurement of the reflected IM3 tone at the input of an RF front-end is shown to be an interesting tool for predicting dysfunctionalities in high frequency circuits with respect to TID. |
| 11:50 | Effects of Total Ionizing Dose on I-V and Low Frequency Noise characteristics in advanced Si/SiGe:C Heterojunction Bipolar Transistors | J. El Beyrouthy\(^1\), A. Vauthelin\(^1\), M. Seif\(^1\), B. Sagnes\(^1\), F. Pascal\(^1\), A. Hoffmann\(^1\), M. Valenza\(^1\), J. Boch\(^1\), T. Maraine\(^1\), S. Haendler\(^1\), A. Gauthier\(^2\), P. Chevalier\(^2\), D. Gloria\(^2\) | 1. IES, University of Montpellier, France  
2. STMicroelectronics, France |
|       |                                                             | This study presents an investigation of the dose response of Si/SiGe HBTs developed with the last generation of BiCMOS technologies. DC electrical characterization and low-frequency noise measurements are carried out to evaluate the post-radiation degradations |
| 12:05 | Investigation of transient radiation effects in GaAs field effect transistors under pulse ionization | I. Metelkin\(^1\), V. Elesin\(^1\), A. Kuznetsov\(^1\), N. Usachev\(^1\) | 1. National Research Nuclear University MEPhI, Russian Federation |
|       |                                                             | Measurements and numerical simulation results of GaAs MESFET and PHEMT response to transient irradiation for different bias conditions are presented. Specific bias conditions and ionization levels were found for detail investigation of radiation effects origin. |
PB-1 Radiative Hardness of GaN HEMTs to TID Effects: COTS for harsh environments
A. Vilas Bôas¹, M. De Melo¹, R. Santos¹, R. Giacomini¹, N. Medina², L. Seixas³, S. Finco³, F. Palomo⁴, A. Romero-Maestre⁴, M. Guazzelli⁵
¹. FEI - Fundação Educacional Inaciana Padre Sabóia de Medeiros, Brazil
². IFUSP, Brazil
³. CTI, Brazil
⁴. Universidad de Sevilla, Spain
⁵. Centro Universitário FEI, Brazil
GaN-COTS transistors were exposed to TID effects by X-rays. Characteristic curves were performed in the On- and Off-state. Switching and temperature tests indicate the GaN is tolerant to TID effects and candidate to harsh environments.

PB-2 Effect of Proton Irradiation Energy on AlGaN/GaN HEMTs fabricated by Ion-implanted Isolation
D. Kim¹, J. Lee², J. Kim², J. Lee¹, J. Lee²
¹. Korea Atomic Energy Research Institute, Korea, Republic of
². Kyungpook National University, Korea, Republic of
The effect of proton irradiation energy on AlGaN/GaN HEMTs fabricated by Ar ion-implanted isolation was evaluated.

PB-3 High-fluence proton induced radiation effects on the AlGaN/GaN high-electron-mobility transistors
S. Yue¹, Z. Lei¹, J. Wang², Y. En¹, X. Zhong², C. Peng¹, Z. Zhang¹, Y. Wang¹
¹. China Electronic Product Reliability and Environmental Testing Research Institute, China
². School of Materials Science and Engineering, Xiangtan University, China
The electrical characteristics and low-frequency noise (LFN) behavior of AlGaN/GaN high-electron-mobility transistors after 3MeV proton irradiation up to a total dose of 5.0×10¹⁴ p/cm² have been investigated in this paper.

PB-4 Total-ionizing-dose Effects in InGaAs MOSFETs with High-k Gate Dielectrics and InP Substrates
S. Bonaldo¹, E. Zhang², S. Zhao², V. Putvais³, B. Parvais³, D. Linten³, S. Gerardin¹, A. Paccagnella¹, R. Reed², R. Schrimpf², D. Fleetwood²
¹. University of Padova, Italy
². Vanderbilt University, USA
³. Imec, Belgium
Total-ionizing-dose response is evaluated for InGaAs MOSFETs at several channel lengths and under different biases. Radiation-induced degradation mechanisms are investigated through DC static measurements and low-frequency noise measurements.

PB-5 TID test results of radiation hardened SiC MOS structures
V. Cantarella¹, F. Pintacuda¹, S. Massetti¹, M. Muschitiello²
¹. St Microelectronics, Italy
². European Space Agency - ESTEC, Netherlands
This paper describe the results about TID test related to SiC PowerMOSfet structures. This study shall be considered as preparatory work supporting the planned development of discrete European radiation-hardened SiC powerMOSFETs for space applications.

PB-6 Combined Effects of Tantalum Ion and Gamma Ray Irradiations on MOS Devices with Atomic Layer Deposited Al2O3 Gate Dielectrics
Z. Zheng¹, H. Zhu¹, X. Chen¹, L. Wang¹, B. Li¹, J. Gao¹, D. Li¹, J. Luo¹, Z. Han¹, J. Liu²
¹. Institute of Microelectronics of Chinese Academy of Sciences, China
². Institute of Modern Physics, Chinese Academy of Sciences, China
MOS devices with Al2O3 dielectrics are irradiated sequentially using gamma rays and 1907 MeV tantalum ions, and the combined irradiation effects on the Al2O3 based MOS devices are investigated and the mechanism is analyzed.
Radiation-induced Degradation Mechanism in Double-SOI pMOSFETs
Y. Huang¹, F. Liu¹, B. Li², B. Li², J. Gao¹, L. Wang², X. Su¹, H. Liu¹, Z. Han¹, J. Luo¹
1. IMECAS, China
2. Institute of Microelectronics, Chinese Academy of Sciences, China

A significant degradation of drain current in Double-SOI pMOSFET is observed after irradiation. The degradation mechanism is analyzed by extracting the related parameters from Y-function. Impact of negative SOI bias on parameter degradation is investigated.

Analysis of Total Dose Effects on a PDSOI n-channel High Voltage Transistor for Analog Applications
F. Perez¹, F. Saigne², A. Michez², E. Furic³, E. Leduc⁴, F. Malou⁵, J. Boch², A. Touboul², F. Wrobel²
1. CNES/MICROCHIP/University of Montpellier, France
2. IES, University of Montpellier, France
3. MICROCHIP, France
4. CNES, France

In this paper, TID irradiations have been performed on a PDSOI n-channel High Voltage transistor for analog applications. ECORCE TCAD modeling software is used to qualitatively analyze and model the physical processes at play.

TID-Induced Breakdown Voltage Degradation in Uniform Doping and Linear Variable Doping SOI p-LDMOSFETs
L. Shu¹, Y. Zhao², L. Wang³, K. Zhao⁴, X. Zhou⁴, K. Galloway⁵, C. Liu⁶, W. Cao⁴, C. Sui⁵, W. Chen⁶, L. Xiao⁶, X. Luo⁶, Y. Li⁸, T. Wang⁶
1. Harbin Institute of Technology, China
2. HIT & BMTI, China
3. BMTI, China
4. UESTC, China
5. Vanderbilt, USA
6. HIT, China
7. UT, China
8. BJUT, China

The BVDS for UD and LVD SOI p-LDMOSFETs is examined after exposure to TID. Results show BVDS degradation with accumulated dose. TCAD simulation is used to gain insight into the mechanism causing BVDS degradation.

Threshold Voltage Shift Saturation in P-Channel Power MOSFET’s under X-ray Irradiation
F. Principato¹, M. Muschitiello², C. Poivey², A. Costantino², V. Cantarella³, L. Abbene¹, F. Pintacuda³
1. Dipartimento Fisica e Chimica-Palermo University, Italy
2. ESA, Netherlands
3. St Microelectronics, Italy

This paper reports on saturation of the threshold voltage shift of P-channel Power MOSFET’s irradiated with X-ray radiation. This effect is not present under 60Co radiation.

Pulsed X-ray irradiation response in the linear voltage regulator LM7805: before and after TID accumulation
R. Li¹, C. He², C. Wang¹, W. Chen¹, J. Li¹, X. Jin¹, C. Qi¹, X. Bai¹, Y. Liu¹, G. Wang¹
1. Northwest Institute of Nuclear Science and Technology, China
2. Xian Jiaotong University, China

Linear voltage regulators LM7805 are irradiated in a Co-60 unit and subsequently irradiated in a pulsed X-ray radiation. The differences in the pulsed-irradiation response before and after the total ionizing dose (TID) accumulation are analyzed.

12:20 Lunch
13:30 Women in Engineering: Networking Coffee & Invited Presentation

Session I FACILITIES AND DOSIMETRY
14:10 Chairs: Jean-Marie Lauenstein (NASA GSFC) & Nancy Postiau (Université Catholique de Louvain)
I-1  Characterizing High-energy Ion Beams with PIPS Detectors
14:15  M. Bagatin1, V. Ferlet-Cavrois2, S. Gerardin3, M. Muschitiello4, A. Paccagnella1, A. Costantino2, G. Santin1, C. Boатегlia-Polo3, R. Garcia Alia4, P. Fernandez Martinez2, M. Kastriotou4
1. University of Padova, Italy
2. ESA, Netherlands
3. DEI - Padova University, Italy
4. CERN, Switzerland
We measured high-energy ion beams using a Passivated Implanted Planar Silicon (PIPS) detector. The importance of accounting for secondaries production in the packaging materials and the presence of items in the beam is highlighted.

I-2  On-Chip Total Ionizing Dose Digital Monitor in Fully-Depleted SOI Technologies
14:30  F. Abouzeid1, B. Valérie1, G. Gasiot1, L. Guénolé1, C. Lecat1, V. Malherbe1, S. Dimitri1, A. Jean-luc2, R. Philippe1
1. STMicroelectronics, France
2. IM2NP, France
This paper presents a digital dosimeter for on-chip total ionizing dose computation. It was designed and fabricated in 28nm and 22nm Fully-Depleted SOI technologies, and experimentally validated with X-rays, gamma rays and alpha particles.

I-3  Fast Neutron Production at Particle Accelerators for Radiation Hardness Assurance Tests
14:45  P. Casolaro1, L. Campajola2
1. Istituto Nazionale di Fisica Nucleare (INFN) - Section of Napoli, Italy
2. Università di Napoli Federico II and INFN-Napoli, Italy
The fast neutron production was carried out with MeV-protons on a lithium target. The modulation of the target thickness and proton current and energy allow production of neutron spectra for DDD and SEE tests.

POSTER PAPERS

PI-1  Remote Measurements of X-rays Dose Rate using a Cerium-doped Air-clad Optical Fiber
J. Bahout1, Y. Ouerdane2, H. El hamzaoui1, G. Bouwmans3, M. Bouazaoui1, A. Cassez1, K. Baudelle1, R. Habert1, A. Boukenter1, S. Girard1, B. Capoen1
1. Laboratoire PhLAM-Université de Lille, France
2. Université de Saint Etienne, France
We designed and fabricated a cerium-doped air-clad optical fiber for ionizing radiations dosimetry. We demonstrate that X-rays dose rates can be measured using this active microstructured fiber in an all-fibered remote configuration.

PI-2  Dosimetric characterization of an irradiation set-up for electronic components testing at the TOP-IMPLART proton linear accelerator
G. Bazzano1, A. Ampollini1, F. Cardelli1, E. Cisbani2, P. Nenzi1, L. Picardi1, M. Piccinini3, C. Ronsivalle1, C. De angelis2, S. Delle monache3, A. Mastrandrea3, L. Blasi3, F. Menichelli3, F. Vigli3, M. Olivieri4, G. Palmerini1, M. Sabatini4
1. ENEA Frascati, Italy
2. Istituto Superiore di Sanità, Italy
3. Università di Bologna, Italy
4. Sapienza Università di Roma, Italy
This contribution describes the irradiation set-up for electronic and space components testing with pulsed 30 MeV proton beam of high instantaneous dose rate provided by the TOP-IMPLART linear accelerator at ENEA Frascati Research Centre
PI-3  Design of 3-D scintillator detector for Compton imaging based on laser engraving
J. Zhang¹, X. Pang¹, L. Shuai², H. Tang¹, B. Feng¹, D. Li², Z. Zhang², L. Wei²
1. Beijing Engineering Research Center of Radiographic Techniques and Equipment, Institute of High Energy Physics, Chinese Academy of Sciences, China
A 3-D scintillator detector pixelated by sub-surface laser engraving in the depth direction is proposed for Compton imaging, which shows good capability on detection efficiency, energy resolution and angle resolution.

PI-4  Investigation of TSL properties of potential fibered-OSL dosimeter materials
M. Benabdesselam¹, F. Mady¹, A. Guttilla¹, W. Blanc¹, H. El hamzaoui², M. Bouazaoui², N. Al helou², J. Bahout², G. Bouwmans², B. Capoen²
1. INPHYNI Université Côte d’Azur, France
2. PhLAM, Université de Lille, France
We report on TSL properties of two doped sol-gel silica glasses. By comparing their performances like sensitivity and kram response, it is shown that they constitute potential candidates for both TSL and OSL dosimetry applications.

PI-5  Influence of temperature and electrical modes on radiation sensitivity and errors of RADFETs
B. Podlepetskы¹, V. Pershenkov², A. Bakerenkov², V. Felitsyn², A. Rodin²
1. MEPhI, Russian Federation
2. NRNU MEPhI, Russian Federation
Influence of temperature and electrical modes on errors and radiation sensitivity of dose sensor based on n-MOSFET have been investigated. Proposed models interpreting the experimental data can be used to predict performances of MOSFET-based dosimeters.

PI-6  Irradiation facilities within the PAC-G: from atmospheric to space applications
M. Letiche¹, R. Varela della giustina¹, U. Köster¹, E. Capria², M. Baylac³, M. Cheymol³, J. Guillermin⁴, N. Chatry⁴, F. Bezerra⁵, J. Beaucour¹
1. ILL, France
2. ESRF, France
3. LPSC, France
4. TRAD, France
5. CNES, France
The Platform for Advanced Characterization of Grenoble (PAC-G) is offering world unique and complementary techniques for HiRel components characterization. Among them low and high-energy neutron SEU testing, preliminary and/or selective heavy ion tests.

PI-7  Upgrade of Low Flux Proton Irradiation Facility for Radiation Effect Test at KOMAC
Y. Kim¹, S. Yun¹, Y. Song¹, H. Kim², H. Kwon³, K. Kim³, Y. Cho¹
1. KOMAC, Korea, Republic of
A new low flux proton irradiation facility is being upgrade with new beam diagnostics and new control system interface in order to efficient beam tuning process and the details will be given in this study.

15:00  POSTER SESSION
Chair: Florent Miller (Nucleitudes)

17:30  End of Wednesday Sessions
TECHNICAL PROGRAM THURSDAY

Invited Talk  30 YEARS OF PARABOLIC FLIGHTS
08:30    S. Rouquette, CNES

Session D  SINGLE EVENT EFFECTS: DEVICES & ICS
09:30    Chairs: Anne Samaras (AIRBUS Defence & Space) & Farokh Irom (NASA-Jet Propulsion Laboratory)

D-1  Reliability analysis of a 65nm Rad-Hard SRAM-Based FPGA for CERN applications
09:35    G. Tsiligiannis¹, C. Debarge², J. Le Mauff², S. Danzeca₁, A. Masi¹
1. CERN, Switzerland
2. NanoXplore, France
In this work, the effects of proton induced radiation on a 65nm Rad Hard SRAM-Based Field Programmable Gate Array (FPGA) are studied. Based on the presented results, the Reliability analysis of this device, is performed.

D-2  Analysis of SET propagation in a system in package point of load converter
09:50    T. Rajkowski¹, F. Saigné², V. Pouget², F. Wrobel², A. Touboul², J. Boch², P. Kohler¹, P. Dubus¹, P. Wang¹
1. 3D-Plus, France
2. IES, University of Montpellier, France
Propagation of SETs in a point of load converter is shown to be dependent on the competition between the negative and positive part of the SET waveform. Results are analyzed and explained using Spice simulation.

D-3  Irradiation Test of 65-nm Bulk SRAMs with DC Muon Beam at RCNP-MuSIC Facility
10:05    T. Mahara¹, S. Manabe¹, Y. Watanabe¹, W. Liao¹, M. Hashimoto¹, T. Saito³, M. Niikura³, K. Ninomiya³, D. Tomono³, A. Sato³
1. Department of Advanced Energy Engineering Science, Kyushu University, Japan
2. Osaka University, Japan
3. Department of Physics, the University of Tokyo, Japan
4. the Graduate School of Science, Osaka University, Japan
5. Research Center for Nuclear Physics (RCNP), Osaka University, Japan
Reliable muon-induced SEU cross section for 65-nm bulk SRAM was measured taking advantage of a DC muon beam. Also, a muonic X-ray measurement was performed to investigate muon stopping positions in the device board.

D-4  Tradeoffs Between RF Performance and SET Robustness in Low-Noise Amplifiers in a Complementary SiGe BiCMOS Platform
10:20    A. Ildefonso¹, N. Lourenco², G. Tzintzarov³, Z. Fleetwood⁴, A. Khachatrian⁵, S. Buchner⁵, D. Mcmorrow⁵, J. Warner⁵, M. Kaynak⁵, J. Cressler¹
1. Georgia Institute of Technology, USA
2. Georgia Tech Research Institute, USA
3. Georgia Tech, USA
4. SpaceX, USA
5. Naval Research Laboratory, USA
7. IHP Microelectronics, Germany
The tradeoffs between RF performance and single-event transient robustness are explored in low-noise amplifiers designed in a complementary SiGe BiCMOS Platform.
Understanding the Impact of Binary Quantization on the Reliability of Convolutional Neural Networks on FPGAs

F. Libano¹, B. Wilson², M. Wirthlin², J. Brunhaver¹
1. Arizona State University, USA
2. Brigham Young University, USA

Through extensive fault-injection experiments, we determine the reliability impact of applying binary quantization to convolutional layers of neural networks on FPGAs, by analyzing the relationships between resource utilization, error criticality and overall accuracy.

POSTER PAPERS

PD-1
Experimental investigation of SEUs Induced by Heavy Ions in 28-nm FDSOI SRAMs
J. Xu¹, Y. Guo¹, R. Song¹, Y. Chi¹, B. Liang¹, C. Hu¹, W. Qu¹
1. College of Computer, National University of Defense Technology, Changsha, Hunan, China

We have performed an irradiation test of heavy ions. Linear energy transfer (LET), temperature, supply volt-age and body bias dependence of single event upset (SEU) cross section in 28-nm FDSOI SRAMs is investigated.

PD-2
Assessment of Current Sensor on Chip for Detecting Neutron-Induced Transients via Body Terminals
R. Possamai bastos¹, J. Dutertre², M. Trindade¹, R. Andreoni Camponogara Viera², O. Potin², S. Rey³, B. Cheymol³
1. Laboratoire TIMA, France
2. Ecole Nationale Supérieure des Mines de Saint-Etienne, France
3. LPSC, France

This work assesses for the first time a body built-in current sensor in a CMOS 65-nm test chip under neutron radiation and laser irradiation. The sensor is effective to detect transient faults induced from both.

PD-3
Heavy Ions Testing of an All-Convolutional Neural Network for Image Classification Evolved by Genetic Algorithms and Implemented on SRAM-Based FPGA
F. Benevenuti¹, I. Lopes¹, F. Lima kastensmidt¹, N. Added², V. P. Aguiar², N. H. Medina³, M. Guazzelli³
1. Universidade Federal do Rio Grande do Sul (UFRGS), Brazil
2. Universidade de São Paulo (USP), Brazil
3. Centro Universitário da FEI (UNIFEI), Brazil

This work investigates the vulnerability of an image classification engine under heavy-ions accelerated irradiation. The engine is based on all-convolutional neural-network trained with the GTSRB traffic sign recognition benchmark and embedded into 28nm SRAM-based FPGA.

PD-4
Simultaneous Single Event Transient (SET) observation on Majority Voter design based on LM139A Quad Voltage Comparators
S. Morand¹, C. Binois¹, H. Claret¹, K. Kruckmeyer², R. Mangeret¹, M. Marin¹, G. Salvaterra³, D. Staerk³
1. Airbus Defence And Space, France
2. Texas Instruments, USA
3. Tesat-Spacecom, Germany

The LM139A majority voter design is identified as sensitive to Simultaneous SETs. Either internal charge sharing or input coupling lead to the function failure. Root cause analysis and mitigation technics are extensively discussed.

PD-5
Impact of Tensor Cores and Mixed-Precision on the Reliability of Matrix Multiplication in GPUs
P. Basso¹, F. Santos¹, P. Rech¹
1. UFRGS, Brazil

We investigate the impact of tensor cores and mixed precision in GPUs reliability. We show that low precision operations are more reliable and tensor core increases the amount of data correctly produced by the GPU.
PD-6  **Inherent Uncertainty in the Determination of Multiple Event Cross Sections in Radiation Tests**
F. Franco¹, J. Clemente¹, G. Korkianⁱ, J. Fabero¹, H. Mecha¹, R. Velazco²

1. Universidad Complutense de Madrid, Spain
2. Université Grenoble-Alpes, CNRS, France

In radiation experiments with too many bitflips, accidentally nearby flipped cells can be misled with a multiple event. In this summary, a general method to determine the expected number of false events is developed.

PD-7  **Single Event Upsets under 14-MeV Neutrons in a 28-nm SRAM-based FPGA in Static Mode**
J. Fabero¹, H. Mecha¹, F. Franco¹, J. Clemente¹, S. Rey², B. Cheymol², M. Baylac², G. Hubert³, R. Velazco²

1. Universidad Complutense de Madrid, Spain
2. Université Grenoble-Alpes, CNRS, France
3. ONERA French Aerospace Laboratory, France

A sensitivity characterization of a Xilinx Artix-7 FPGA against 14.2 MeV neutrons is presented. Errors in flip-flops, BRAMs and configuration memory, and the applicability of statistical methods for extracting MCUs on this device are discussed.

PD-8  **Reliability analysis of an Ethernet-based solution for data transmission in the CERN radiation environment**
G. Gnemmi¹, G. Tsiligiannis¹, A. Masi¹, S. Danzeca¹

1. CERN, Switzerland

At CERN the necessity for a communication link reliable under radiation and compatible with a wide range of devices has prompted to the qualification of an Ethernet based solution.

PD-9  **Vertical Line Fault Mechanism Induced by Heavy Ions in an SLC NAND Flash**
V. Gupta¹, A. Bosser², L. Matana luza³, D. Söderström⁴, A. Javanainen⁴, H. Kettunen⁴, J. Praks⁵, K. Voss⁶, A. Virtanen⁴, L. Dilillo³

1. ESA/ESAC, Belgium
2. Aalto University, Finland
3. LIRMM, France
4. University of Jyväskylä Physics Department, Finland
5. GSI Helmholtzzentrum für Schwerionenforschung, Germany

The vertical line fault mechanism occurring in NAND flash devices under heavy-ion irradiation is described in detail. The location where the fault is generated as well as the recovery sequence are identified.

PD-10  **Evaluating Soft-Core RISC-V Processor in SRAM-based FPGA under Radiation Effects**
A Oliveira¹, F. Benevenuti¹, L. Contreras¹, F. Lima Kastensmidt¹, N. Added², V. Aguiar², N. Medina², M. Silveira³

1. UFRGS, Brazil
2. USP, Brazil
3. Centro Universitario da FEI, Brazil

This work evaluates the susceptibility of RISC-V processor embedded into SRAM-based FPGA through heavy ions and accumulated fault injection experiments. Results demonstrated the RISC-V outcomes are improved three times by combining mitigation techniques.

PD-11  **Impact of Incident Angle on Negative Muon-induced SEU Cross Section of 65-nm Bulk SRAM**
W. Liao¹, M. Hashimoto², S. Manabe³, Y. Watanabe³, S. Abe⁴, M. Tampo⁵, S. Takeshita⁵, Y. Miyake⁵

1. Kochi University of Technology, Japan
2. Osaka University, Japan
3. Kyushu University, Japan
4. Japan Atomic Energy Agency, Japan
5. High Energy Accelerator Research Organization (KEK), Japan

65-nm bulk SRAMS were irradiated with negative muons at vertical and tilt direction to investigate the angular dependence on SEU cross section. Results show tilt irradiation leads to higher peak energy and different voltage dependence.
PD-12 **Heavy-Ion Induced Single-Event Upset Response for Flip-Chip Packaged SRAM Device in 14-nm Bulk FinFET Technology**
M. Lihua¹, Z. Zhang², B. Ye¹, J. Liu¹, T. Tong³
1. the Institute of Modern Physics, Chinese Academy of Sciences, China  
2. the Science and Technology on Reliability Physics and Application Technology of Electronic Component Laboratory, China  
3. the Institute of High Energy Physics, Chinese Academy of Sciences, China  

Experiment and simulation for flip-chip packaged SRAM device in 14-nm Bulk FinFET Technology suggest MCU is the dominant factor affecting the upset cross-section and the concept of effective LET may inapplicable in 3-D structure device.

PD-13 **CLASS: on-Chip Lightweight Accurate SEU/SET event classifier**
S. Thomet¹, S. De-Paoli¹, F. Ghaffari², F. Abouzeid¹, O. Romain², P. Roche¹
1. STMicroelectronics, France  
2. ETIS UMR 8051 ENSEA, France  

This paper presents an on-chip error classifier for Soft-Error Rate characterization of cells under radiations. Implemented on top of flip-flop chains, it counts Single-Event Upset and Single-Event Transient at mission profile.

PD-14 **Towards a Characterization of Vulnerability of XCR4C ASIC on Heavy-Ion Induced Transient Events**
B. Li¹, B. Lu², H. Jia³, Y. Chen³, W. Wei³, F. Zhang³, Z. Su¹, J. Gao¹, C. Wang³, W. Zhao³, H. Liu¹  
1. Institute of Microelectronics, Chinese Academy of Sciences, China  
2. Institute of High Energy Physics, Chinese Academy of Sciences, China  

Transients with durations of dozens of seconds in a rad-hard four-channel CDS ASIC (XCR4C) for X-ray CCD were observed during 181Ta31+ ions irradiation and were attributed to the complementary feedback mechanism in the bias circuit.

**Session F**

**HARDENING TECHNIQUES**

11:15 David Truyen (MICROCHIP) & Cristina Plettner (ESA)

F-1 **Evaluation of Soft-Error Tolerance by Neutrons and Heavy Ions on Flip Flops with Guard Gates in a 65 nm Thin BOX FDSOI Process**
M. Ebara¹, K. Yamada¹, K. Kojima¹, Y. Tsukita¹, J. Furuta¹, K. Kobayashi¹  
1. Kyoto Institute of Technology, Japan  

We evaluated soft-error tolerance by neutrons and heavy ions on four types of flip flops. We revealed that the guard-gate structure has high soft-error tolerance by low-LET heavy ions.

F-2 **New Single Event Transient phenomenon in 28FDSOI and its impact on hardening**
G. Gasiot¹, F. Abouzeid², V. Malherbe¹, J. Damiens¹, F. Monsieur¹, C. Lecat mathieu de boissac¹, D. Soussan¹, V. Lorquet¹, T. Thery¹, P. Philippe roche¹  
1. STMicroelectronics, France  

A novel Single Event Transient mechanism is measured for the first time in FDSOI28 technology. Associated detection mechanism and impact on radiation hardening are discussed.

F-3 **SE Response of Guard-Gate FF in 16-nm and 7-nm Bulk FinFET Technologies**
J. Cao¹, L. Xu¹, B. Bhuva¹, S. Wen², C. Cazzaniga³, C. Frost⁴  
1. Vanderbilt University, USA  
2. cisco, USA  
3. STFC, United Kingdom  
4. ISIS Neutron and Muon Facility, United Kingdom  

SER of Guard-Gate Flip-Flop and D-FF is evaluated at 16nm and 7nm nodes. Heavy-ion and alpha test results show GG-FF have significant improvement of SER. The number of short SET pulses is also estimated.
Error Detection and Mitigation of Data-Intensive Microprocessor Applications using SIMD and Trace Monitoring
M. Peña-Fernandez, A. Lindoso, L. Entrena, M. Garcia-valderas
1. Arquimea Ingenieria SLU, Spain
2. Universidad Carlos III, Spain
This work proposes a novel software error mitigation approach using SIMD coprocessor to accelerate computation over redundant data, combined with Trace Monitoring for control-flow error detection. The proposed approach was tested with neutron radiation.

An Approximate Error-Detection Technique for Multi-Core Real-Time Systems
1. UFRGS, Brazil
2. IES, University of Montpellier, France
3. École Centrale de Lyon - Lyon Institute of Nanotechnology, France
This paper presents a parallel error detection method evaluated using laser fault injection on a dual-core ARM processor. It exploits approximation to improve performance. Results are satisfactory, especially with algorithms that are not memory intensive.

A Multi-objective Optimization Framework to Design Soft-Error-Immune Circuit
Y. Li, J. Han, Y. Han, X. Zeng
1. Fudan University, China
With the help of neural network algorithm and NSGA-II algorithm, this study investigates a multi-objective optimization model as a guidance on Soft-Error-Immune circuit design to explore a trade-off between power, area and Soft Error Rate.

A Low-Overhead Radiation Hardening Approach using Approximate Computing and Selective Fault Tolerance Techniques at the Software Level
A. Aponte-Moreno, F. Restrepo-calle, C. Pedraza
1. Universidad Nacional de Colombia, Colombia
This paper presents a method to reduce execution time overheads in the design of radiation-induced fault-tolerant systems by means of Approximate Computing and selective FT software techniques. A case study for MSP430 microcontroller is presented.

Configuration Memory Scrubbing of the Xilinx Zynq-7000 FPGA using a Mixed 2-D Coding Technique
1. University of Piraeus, Greece
2. European Space Agency, ESTEC, Netherlands
3. European Organization for Nuclear Research (CERN), Switzerland
The paper presents a configuration memory scrubbing approach for the Xilinx Zynq-7000 devices. It combines the embedded ECC code of the FPGA and an interframe, interleaved parity scheme to form a mixed two-dimensional coding scheme.

Experiment and Simulation on Single-Event Transient Effects of the MOS Capacitor in LDO
C. Sui, Y. Zhao, W. Cao, L. Wang, X. Han, J. Liu, L. Shu, T. Li
1. Beijing Microelectronics Technology Institute, China
2. Electronic Science and Technology Department, Harbin Institute of Technology, China
Performance of a RHBD LDO is verified by experiments. According to the experimental results of LDOs, a novel SET sensitive mechanism of compensation MOS capacitor is found and the mitigation method is pro-posed.
PF-3  **Self-robust Non-Volatile C-element for Single Event Upset enhanced tolerance**

O. Coi¹, G. Di Pendina², G. Prenat², L. Torres³

1. INAC-SPINTEC CEA/CNRS/UGA/INP-CNES-LIRMM/CNRS/University of Montpellier, France
2. INAC-SPINTEC CEA/CNRS/UGA/INP, France
3. LIRMM CNRS-University of Montpellier, France

The first radiation hardened Non Volatile C-element is presented. This state holding circuit reduces the counting of sensitive nodes while addressing the undesirable MTJ switching issue. Immunity against SEU of around 300 fC has achieved.

PF-4  **An open source embedded-GPGPU model for the accurate analysis and mitigation of SEU effects**

B. Du¹, E. Rodriguez¹, M. Sonza Reorda¹, L. Sterpone¹

1. Politecnico di Torino, Italy

In this paper, we propose a new hardware and synthesizable model of an embedded General Purpose Graphic Processing Unit (GPGPUs) designed for analyzing and mitigating radiation effects. Comparative SEU injection experiments confirms the model effectiveness.

PF-5  **Exploiting Transistor Folding Layout as RHBD technique against Single-Event Transients**

Y. Quadros de Aguiar¹, F. Wrobel¹, J. Autran², F. Kastensmidt¹, P. Leroux², F. Saigné¹, V. Pouget¹, A. Touboul¹

1. Université de Montpellier, IES - UMR UM/CNRS 5214, France
2. Aix-Marseille University, France
3. UFRGS, Brazil
4. KU Leuven University, Belgium

This work analyzes the efficiency of transistor folding combined with diffusion splitting in improving the Single-Event Transient robustness of digital circuits. Results show that these techniques can reduce cross-section and increase threshold Linear Energy Transfer.

PF-6  **Circuit-Level Hardening Techniques to Mitigate Soft Errors in FinFET Logic Gates**

A. Lackmann zimpeck¹, L. Artola², G. Hubert², C. Meinhardt³, F. Lima Kastensmidt¹, R. Reis¹

1. UFRGS, Brazil
2. ONERA, France
3. UFSC, Brazil

Transistor reordering and insertion of decoupling cells are explored to reduce the SE susceptibility of circuits designed in FinFET technology. This work shows that robustness improves up to 37% and 10% with the respective methodologies.

PF-7  **LVDS Transmitter for Cold-Spare Systems in High Flux Environments**

T. Yoshikawa¹, A. Aoyama¹, T. Iwata¹, K. Kobayashi²

1. Toyama Prefectural University, Japan
2. Kyoto Institute of Technology, Japan

LVDS Transmitter (TX) has been proposed for cold-spare systems. A test-chip of the TX shows remarkable suppression of BER degradation compared to commercial device in 10 times higher flux environment of 84Kr17+.

PF-8  **Radiation hardened analog-to-digital convertor with automatic offset voltage compensation**

V. Felitsyn¹, A. Bakerenkov¹, A. Zhukov¹, V. Butuzov¹, Y. Bocharov¹, V. Pershenkov¹, A. Rodin¹, V. Telets¹, V. Belyakov¹

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

Radiation hardened ADC with automatic offset voltage compensation was developed. TID radiation effect in the ADC was investigated. Developed device can be considered as a good technical decision for self-diagnostic systems of satellites and spacecrafts.
Displacement Damage Effects Mitigation Approach for HBT RF Frequency Synthesizers
D. Sotskov\textsuperscript{1}, V. Elesin\textsuperscript{1}, A. Kuznetsov\textsuperscript{1}, N. Zhidkov\textsuperscript{1}, I. Metelkin\textsuperscript{1}, K. Amburkin\textsuperscript{1}, D. Amburkin\textsuperscript{1}, N. Usachev\textsuperscript{1}, D. Boychenko\textsuperscript{1}

1. National Research Nuclear University MEPhI (Moscow Engineering Physics Institute), Russian Federation
This paper was focused on the design issues of RF bipolar ICs for extreme environment applications. Design approach for RF bipolar ICs based on specialized HBT macro-models and hardening techniques was presented and carried out.

DATA WORKSHOP
Chairs: Philippe Adell (NASA JPL) & Geraldine Chaumont (STMicroelectronics)

Photonic 5 Gbps and 10 Gbps Transceiver Radiation Test Summary
R. Logan\textsuperscript{1}, D. Basuita\textsuperscript{2}
1. Glenair, USA
2. Glenair Ltd., United Kingdom

Radiation test results for 5Gbps and quad-channel 10Gbps VCSEL-based optical transceivers are presented including SEL, heavy-ion and proton SEE, and TID data for the 5Gbps; and SEL and heavy-ion SEE for the 10Gbps device.

Mixed-Field Radiation Qualification of a COTS Space On-Board Computer along with its CMOS Camera Payload
A. Coronetti\textsuperscript{1}, F. Manni\textsuperscript{2}, J. Mekki\textsuperscript{2}, D. Dangla\textsuperscript{2}, C. Virmontois\textsuperscript{2}, N. Kerboub\textsuperscript{2}
1. CERN, France
2. CNES, France

The system-level radiation characterization of a full space COTS-based system in mixed-field environment is presented. The critical functional aspects affecting system reliability are analyzed and predictions and actions for meeting the RHA objectives are highlighted.

Application of effective LET approach for modern CMOS devices
D. Bobrovsky\textsuperscript{1}, A. Akhmetov\textsuperscript{1}, A. Smolin\textsuperscript{1}, A. Chumakov\textsuperscript{1}
1. NRNU MEPhI/SPES, Russian Federation

Applicability of effective LET concept to SEU testing of modern CMOS devices was investigated. Heavy ion irradiations of two 28nm FPGAs were performed for a wide range of LET values and angles of incidence.

Total Ionizing Dose and Single-Events characterization of Xilinx 20nm Kintex UltraScale™
P. Maillard\textsuperscript{1}, J. Barton\textsuperscript{1}, M. Hart\textsuperscript{1}
1. XILINX Inc., USA

This paper examines the total ionizing dose (TID), single event upset (SEU) and latchup (SEL) response of Xilinx 20nm Kintex UltraScale™ for space applications. The Single Event Mitigation IP tool SEU response is also evaluated.

Single Event Effect Characterization of the GR740 Rad-Hard Quad-Core LEON4FT System-on-Chip
L. Tambara\textsuperscript{1}, F. Hernandez\textsuperscript{1}, F. Sturesson\textsuperscript{1}, M. Hjorth\textsuperscript{1}, J. Andersson\textsuperscript{1}, R. Weigand\textsuperscript{2}
1. Cobham Gaisler, Sweden
2. ESA, Netherlands

This work presents the SEE characterization of the Cobham Gaisler’s GR740 SoC. The low rate of functional errors recorded in application-level testing under irradiation demonstrates the effectiveness of the radiation-hardening scheme selected for this device.
DW-6 SEE & TID characterization for a GHz class PowerPC rad tolerant microprocessor – PC8548E (Jan. 2019)
M. Ball1, Y. Rialland1, O. Bonnet1, T. Guillema1
1. Teledyne e2v, France
The PC8548E GHz class PowerPC rad tolerant microprocessor using the CMOS 90nm SOI technology from NXP, has successfully passed the TID test up to 100KRad and the Heavy Ions test (SEL immunity up to 86MeV).

DW-7 Reliability of a DLS 3D scanner system in the radiotherapy environment
S. Cotta1, R. Höfling1
1. ViALUX Messtechnik+Bildverarbeitung GmbH, Germany
The radiation-hardness of a 3D scanner system for radiotherapy is evaluated during a radiation test at a nuclear reactor. The reliability of the Direct-Link-Sensor (DLS) has been investigated after high levels of irradiation.

DW-8 Radiation Effects (Single Event Effects and Total Ionization Dose) on Commercial-Off-The-Shelf DDR3 SDRAM for ESA JUICE Mission
B. Tanios1, F. Tilhac1, F. Lochon1, O. Perrotin1, P. Fontana1, B. Forgerit1, F. Guerre1, C. Poivey2
1. Hirex Engineering, France
2. ESA, Netherlands
This work presents a comparative study of Total Ionization Dose (TID) and Single Event Effects (SEE) radiation sensitivity of three commercial DDR3 SDRAM memories for the ESA JUpiter ICy moons Explorer (JUICE) Mission.

DW-9 Radiation Tolerance of RHBD techniques on a SiGe BiCMOS 350 nm ASIC technology
S. Chen1, D. Prêle1, F. Voisin1, P. Laurent1, A. Goldwurm1
1. AstroParticle and Cosmology Laboratory, France
This paper presents radiation tolerance evaluation of an ASIC with RHBD techniques based on a SiGe BiCMOS 350nm technology. The TID and SEL have been tested, and hardened ability of our design are discussed.

DW-10 2019 Compendium of Recent Test Results of Single Event Effects Conducted by the Jet Propulsion Laboratory’s Radiation Effects Group
G. Allen1, S. Vartanian3, F. Irom1, S. Guertin1, A. Bozovich1, S. Zajac1, W. Parker1, P. Adell1, A. Daniel1, M. O’Connor1
1. NASA JPL, USA
This paper reports heavy ion, proton, and pulsed-laser induced SEE results for a variety of microelectronics targeted for possible use in JPL spacecraft. The compendium covers devices tested within from August 2017 through March 2018.

DW-11 SEE Responses of Mos-SiC, Mos-Si and SiC Mosfet
F. Pintacuda5, S. Massetti2, M. Muschitiello5, A. Javanainen3, V. Cantarella1
1. STMicroelectronics, Italy
2. ESA-ESTEC, Netherlands
3. University of Jyvaskyla, Finland
This paper report the SEE results measured on Mos-SiC, Mos-Si and SiC Mosfet. The goal of this study is to characterize SiC oxides gate as one of the key factors for rad-hard SiC MOSFET development.

DW-12 Total Ionizing Dose Characterization of 28 nm PolarFire SONOS-based FPGA
N. Rezzak1, J. Wang3, A. Cai1, F. Hawley3, E. Hamdy1
1. Microchip, USA
This paper presents Total Ionizing Dose (TID) results on 28nm PolarFire™ SONOS-based FPGA. Gamma and X-ray induced TID effects at the device and product level are presented and discussed.
**TID Radiation Effects of 1Gb COTS NOR Flash Memories for the ESA JUICE Mission**

S. Vargas-Sierra¹, B. Tanios², J. González-Ijúján¹, F. Tilhac², M. Domínguez¹, C. Poivey³

1. Alter Technology, Spain
2. Hirex, France
3. ESTEC (TEC-QEC), European Space Agency, Netherlands

This work presents the comparative study of the TID radiation sensitivity of three COTS NOR Flash memories for the ESA JUPiter ICy moons Explorer (JUICE) Mission.

**Stuck and Weakened SDRAM Cells due to Heavy-Ion Irradiation**

D. Soderstrom¹, L. Matana luza², A. Bosser³, T. Gil², K. Voss⁴, H. Kettunen⁵, A. Javanainen⁵, L. Dilillo²

1. University of Jyväskylä, Finland
2. Laboratoire d’Informatique, de Robotique et de Microélectronique de Montpellier (LIRMM), France
3. Aalto University School of Electrical Engineering, Finland
4. GSI Helmholtzzentrum für Schwerionenforschung, Germany
5. RADEF, Finland

Stuck and weakened bits in the ISSI 512 Mb SDRAM has been investigated in irradiation experiments with a heavy ion microbeam in the GSI facility.

**Radiation characterization of COTS MicroSD Memories for CERN applications**

G. Piscopo¹, C. Mcallister¹, G. Tsiligiannis¹, S. Danzeca¹, A. Masi¹

1. CERN, Switzerland

The sensitivity of several MicroSD Cards under the harsh radiation environment of the Large Hadron Collider (LHC) at CERN is analysed in this paper. The radiation effects of each MicroSD Card will be presented.

**Compendium of Radiation-induced Effects on μProcessors for CERN applications**

G. Tsiligiannis¹, A. Masi¹, S. Danzeca¹

1. CERN, Switzerland

In this paper, we analyze the sensitivity of four ARM-based microprocessors under Proton induced radiation. The purpose of the study is to explore the reliability limitations of these devices under the CERN radiation environment.

**Single event sensitivity and de-rating of SiC power devices to heavy ions and protons**

M. Steffens¹, S. Hoeffgen², T. Kündgen¹, E. Paschkowski¹, M. Poizat², D. Wölk³

1. Fraunhofer INT, Germany
2. ESA, Netherlands

We present SEE tests on SiC devices. The data were taken across four campaigns at UCL, GANIL, H8 beamline at CERN and protons at the research centre Jülich. Significant derating is required across all LETs.

**Single Event Effects by atmospheric neutrons in commercial (COTS) normally-off GaN HEMTs**

D. Wölk³, S. Hoeffgen¹, E. Paschkowski¹, M. Steffens¹

1. Fraunhofer INT, Germany

We present the results of SEE testing of COTS high power normally-off GaN-devices with an atmospheric-like neutron spectrum. Three different designs of GaN-HEMTs an one SiC-MOSFET were tested at different voltages and crosssections were determined.

**Voltage Supervisors Post Heavy Ion Irradiation Behavior After Holding in SEL**

S. Vorobiev³, O. Bakhirko³, L. Bakirov³, P. Chubunov³, V. Anashin³, A. Koziukov³, S. Iakovlev³

1. Branch of JSC URSC-ISDE, Russian Federation

In this study we performed the radiation tests on the TPS3305-18DGN and MAX6755UKLD3+T voltage supervisors to characterize its resistance to heavy ion irradiation.
DW-20 SEE Test Results for different analog, digital-analog and digital devices various integration levels
A. Kalashnikova¹, P. Chubunov², S. Iakovlev³, A. Koziukov¹, T. Maksimenko¹, V. Lykov¹, K. Bu-khasan¹, T. Napolova¹, S. Kolpachkov¹, I. Maslennikova¹, N. Bondarenko¹, V. Lykov¹, L. Arutyunyan¹, Y. Gladysheva¹, V. Koptun¹, M. Shekhovtsov¹, A. Klyayn¹, L. Bakirov¹, N. Zakharenkova¹, P. Kurkova¹, S. Vorobiev¹, O. Bakhirko¹
1. Branch of Joint - Stock Company “United Rocket and Space Corporation” - “Institute of Space Device Engineering” (Branch of JSC URSC - ISDE), Russian Federation

The paper presents heavy-ion test results of different devices for a wide temperature range. LET thresholds for SET, SEL, Supply voltage Safe Operating Area and Destructive Failure have been obtained.

DW-21 Total Dose and Single-Event Effects Test Results of the Intersil ISL7x814SEH High Current Driver
W. Newman¹, N. Van vonno², L. Pearce², E. Thomson², A. Robinson², D. Turner²
1. Renesas Electronics America, USA
2. Renesas, USA

We report the results of total ionizing dose (TID) and destructive and nondestructive single-event effects (SEE) testing of the Intersil ISL72814SEH and ISL73814SEH radiation hardened, high-voltage, high-current, driver circuits.

DW-22 Recent Single Event Transients, Upsets, and Latchup Test Results for TPS3307-18, TL1431, INA129, AM26LV31 & 32 Electronic Parts
J. Hatch¹, B. Butterworth²
1. OSU-Nuclear Reactor Laboratory, USA
2. L3-Avionics, USA

SEL, SET, SEU test results presented for automotive grade COTS parts: TPS3307-18, TL1431, INA129, AM26LV31 & 32 Electronic Parts

DW-23 Characterizing Neutron-Induced SDC Rate of Matrix Multiplication in Tesla P4 GPU
K. Ito¹, W. Liao¹, M. Hashimoto¹, J. Kuroda¹, S. Manabe², Y. Watanabe², S. Abe³, M. Harada³, K. Oikawa³, Y. Miyake⁴
1. Osaka University, Japan
2. Kyushu University, Japan
3. Japan Atomic Energy Agency, Japan
4. High Energy Accelerator Research Organization, Japan

This work experimentally investigates neutron-induced SDC rate in matrix multiplication on Nvidia Tesla P4. Results indicate the hardware resource that is not disclosed to GPU users contributes to more than half of overall SDC rate.

DW-24 TID Test Results of LVDS Driver and Receiver ICs with Extended Common Mode Capability
Y. Tcherniavskaya¹, V. Burkhay¹, A. Rocke¹, V. Shunkov¹, F. Gerfers²
1. Space IC GmbH, Germany
2. Technical University of Berlin, Germany

This report provides results of TID robustness tests of LVDS driver and receiver. 56 krad (Si) hardness with full performance has been achieved. With certain limitations circuits are working up to 100 krad (Si).

DW-25 Measuring SER and NBTI by Neutron Irradiation Between Volatile SRAM-based and Nonvolatile Flash-based FPGAs
Y. Kawano¹, Y. Tsukita¹, J. Furuta¹, K. Kobayashi¹
1. Kyoto Institute of Technology, Japan

We compared the SRAM-based and flash-based FPGAs to investigate their radiation hardness. Those results show that in the SRAM-based FPGA must be rebooted or configuration memory must be refreshed more frequently than the flash-based one.
The subject is based on SAMV71RT Cortex® M7 radiation tolerant product addressing New Space requirements. This document proposes the description of the device capability against radiation environment. The poster describes TID and Heavy ions results.

16:15  RADECS GENERAL ASSEMBLY

17:30  End of Thursday Sessions

18:30  Bus departure for Gala Dinner
Session G: RADIATION HARDNESS ASSURANCE
09:00
Chairs: Pavel Chubunov (Branch of JSC URSC-ISDE) & Pierre_xiao Wang (3D PLUS)

G-1: Radiation Specification and Testing of Heterogenous Microprocessor SOCs
09:05
S. Guertin¹, R. Some¹, P. Nsengiyumva², E. H. Cannon³, M. Cabanas-Holmen², J. Ballast²
1. Jet Propulsion Laboratory, California Institute of Technology, Pasadena, CA 91109
2. Boeing Research & Technology, Seattle, WA, 98195

Developing new RHBD microprocessors risks sacrificing processing performance for system-wide radiation requirements. Modern SOCs are heterogenous in design and performance goals for subsystems. New RHBD devices benefit from heterogenous radiation requirements and testing for subsystems.

G-2: Six-Faces Induced Margins on Dose Calculation and Proposal for a New Satellite Geometry Exchange method
09:20
A. Varotsou¹, P. Pourrouquet¹, R. Benacquista¹, R. Mangeret¹, L. Pater³, G. Santin⁴, H. Evans⁴, D. Stanardovski⁵, R. Ecoffet⁵
1. TRAD, France
2. Airbus Defense and Space France, France
3. Airbus Defense and Space UK, United Kingdom
4. ESA, Netherlands
5. CNES, France

The 6-faces method is commonly used for geometry information exchange between primes and subcontractors. Margins induced by this method were identified and analyzed for a geostationary mission. A new method is proposed with promising results.

G-3: Thermal Neutron Induced SEUs in the LHC Accelerator Environment
09:35
M. Cecchetto¹, R. Garcia Alia¹, F. Wrobel², M. Tali³, O. Stein¹, G. Lerner¹, K. Bilko¹, Y. Kadi¹, S. Danzeca¹, M. Brucoli¹
1. CERN, Switzerland
2. University of Montpellier, France
3. CERN/ESA/University if Jyvaskyla, Switzerland

In addition to high-energy hadrons, thermal neutrons are a major concern in terms of SER for electronics in the LHC accelerator. The related RHA considerations are derived analysing the radiation environment and state-of-the-art component sensitivity.

G-4: COTS Optocoupler radiation qualification process for LHC applications based on mixed-energy neutron irradiations
09:50
R. Ferraro¹, G. Foucard¹, A. Infantino¹, L. Dilillo², M. Brugger¹, A. Masi¹, R. Alia¹, S. Danzeca¹
1. CERN, Switzerland
2. LIRMM, France

In this work, a new method of qualifying COTS-based optocouplers adapted to the neutron dominated LHC radiation environment is studied. The responses of components made of different materials irradiated with protons and neutrons are analyzed.

POSTER PAPERS
Contactless Approaches for the Electronic Device Heating during Radiation Hardness Assurance Tests for Single-Event Effects
E. Nekrasova1, E. Mitin1, P. Gromov1, V. Anashin2
1. LLC NPC Granat, Russian Federation
2. Branch of JSC URSC - ISDE, Russian Federation

Different approaches to perform the electronic device heating during radiation hardness assurance tests are discussed. A new heating approach based on the use of ceramic infrared heaters is presented along with experimental results.

Evaluation of ELDRS on Bipolar Devices Using Temperature-Switching Irradiation
X. Li1, W. Lu1, X. Wang1, X. Yu1, J. Sun1, M. Liu1, S. Yao1, Y. Chang1, Q. Guo1, C. He1
1. Xinjiang Technical Institute of Physics and Chemistry, China

Based on the first-principles understanding of interface-trap buildup and annealing, a temperature-switching irradiation (TSI) sequence is shown to be a conservative test for ELDRS at ultra-low dose rates in linear bipolar devices.

Method for System-level testing of COTS electronic board under High Energy Heavy Ions
A. De Bibikoff1, P. Lamberbourg1
1. ZODIAC DATA SYSTEMS, France

We describe a method to characterize the SEE sensitivity of an electronic system. The tests are in air without opening the devices, with LETs up to more than 40 Mev·cm²·mg⁻¹. TRIM is used for calculations.

Extreme Value Based Estimation of Critical Single Event Failure Probability
G. Zebrev1, A. Galimov2, I. Fateev2, U. Rustem3
1. National Research Nuclear University MEPhI, Russian Federation
2. JSC NIIMA Progress, Russian Federation
3. Research Institute of Scientific Instruments, Russian Federation

A new survival probability function of ICs under space ion impact is proposed. Unlike the conventional approach, the function is based on the extreme value statistics which is relevant to the critical single event effects.

Non-Stable Latchups in CMOS ICs under Pulsed Uniform Laser Irradiation
I. Shvetsov-Shilovskiy1, A. Chumakov1, A. Pechenkin1, D. Bobrovsky1
1. NRNU MEPhI, Russian Federation

The paper concerns experimental results on latchup in CMOS ICs with holding voltage close to their normal supply voltage. The radiation test results are presented as well as the discussion of non-stable latchup origin mechanisms.

10:05 Break

RADIATION ENVIRONMENTS
10:35 Chairs: Athina Varotsou (TRAD) & Grigory Protopopov (Branch of JSC URSC - ISDE)

A new model for the 1-10 MeV proton fluxes (part of ONERA GREEN-V3 model)
A. Sicard1, S. Bourdarie1, D. Lazaro1, D. Standarovski2, R. Ecoffet2, L. Lanzerotti3, A. Gerrard3
1. ONERA, France
2. CNES, France
3. NJIT, USA

A new version of the ONERA GREEN model is in development, with a focus on 1-10 MeV proton fluxes. Measurements the dual Van Allen Probes spacecraft and from NOAA-POES spacecraft have been used.
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| H-2     | How much solar cycle variations impact long term effect predictions at LEO? | S. Bourdarie¹, P. Calvel², C. Barillot³, L. Rey³, T. Parrinello³, B. Hoyos³, R. Ecoffet⁴ | 1. ONERA, France  
2. TAS, France  
3. ESA, Italy  
4. CNES, France |
|         |                                                                       | An 8 year long flight database from an EDAC implemented onboard an altimeter flying on CryoSat-2 spacecraft at 715 km altitude is analyzed to investigate on solar cycle variations impact on long term effect predictions. |
| H-3     | Space Weather Measurements From New Generation GOES Spacecraft (GOES-16 and GOES-17) | B. Dichter¹, G. Galica¹ | 1. Assurance Technology Corporation, USA |
|         |                                                                       | New space weather measurement capabilities are available on new generation GOES spacecraft. Spacecraft instruments will be described. Several examples of space weather data of interest for scientific and engineering studies will be presented. |
| H-4     | A proton detector for energies from 2MeV to 20MeV                      | M. Ruffenach¹, S. Bourdarie¹, J. Mekki², D. Falguère¹, J. Vaillé³, J. Carron² | 1. ONERA, France  
2. CNES, France  
3. IES, University of Montpellier, France |
|         |                                                                       | The objective of this study is to extend capabilities of the CNES-ONERA radiation monitor ICARE-NG by adding a low energy proton sensor. Response functions and count rates are calculated using Monte-Carlo simulations and AP-8/AE-8 models. |
| H-5     | Inter-Comparison of Ionizing Doses from Space Shielding Analyses using MCNP, Geant4, FASTRAD, and NOVICE | B. Jun¹, L. Martinez Sierra¹, B. Zhu¹, I. Jun¹ | 1. NASA-Jet Propulsion Laboratory, USA |
|         |                                                                       | Total ionizing doses (TID) are computed using FASTRAD, NOVICE, MCNP, and Geant4 for space radiation shielding analysis, and the results are compared to better understand their predictive capabilities for TID in very high-energy electron environments. |

**POSTER PAPERS**

**PH-1**  
Comparison of Ray-Tracing and Reverse Monte-Carlo Methods: Application to GEO orbit  
R. Benacquista¹, P. Pourrouquet¹, A. Varotsou¹, R. Mangeret², C. Barillot³, G. Santin⁴, H. Evans⁴  
1. TRAD, France  
2. Airbus Defense and Space France, France  
3. TAS, France  
4. ESA, Netherlands  
We present a comparison between Ray-Tracing and Reverse Monte-Carlo methods for dose calculation on GEO orbit. Realistic models of platforms, units and components were considered.

**PH-2**  
Design Environment for Internal Electrostatic Discharge  
W. Kim¹, J. Chinn¹, I. Jun¹, H. Garrett¹  
1. NASA JPL, USA  
The one of most important task of the iESD assessment is to define the relevant environment. We show how the iESD design environments of Juno mission and Europa Clipper mission have been determined.
PH-3  Linking Single Event In-Orbit Data to Space Weather
P. Hornung¹, A. Menicucci², G. Mandorlo³, G. Furano³, M. Prochazka³
1. TU Delft, Germany
2. TU Delft, Netherlands
3. ESA ESTEC, Netherlands
We study Sentinel 2A+B single event counters. Influence of space weather and device degradation on event rate, as well as the movement of the South Atlantic Anomaly, are extracted. Peculiar differences exist between the satellites.

PH-4  Method for Estimating the LET Spectrum Using Data from SEE Monitors Based on SRAM
E. Mrozovskaya¹, V. Anashin¹, G. Protopopov¹
1. Branch of JSC URSC - ISDE, Russian Federation
The method for estimating LET spectra using the data of SEE monitors using the existing heavy ions models is proposed. The accuracy of the method is estimated taking into account variations in space environment characteristics.

PH-5  Analysis of the Drift of the South Atlantic Anomaly from ICARE’s flight data
M. Aubry¹, V. Costes-ori², D. Standarovsky³, R. Ecco²
1. CNES / Xblue / Laboratoire Hubert Curien / Politecnico di Bari, France
2. CNES, France
We investigate the drift of the South Atlantic Anomaly from flight data. To study the drift of the anomaly, we mainly focused on the area, the maximum proton flux values and the centroid.

PH-6  Dose measurements and simulations of the RADFETs response onboard the ALPHASAT CTTB experiments
J. Sampaio¹, P. Gonçalves¹, C. Pinto², T. Sousa², P. Ribeiro³, C. Poivey⁴
1. LIP - Lab. Instrumentação e Físico Experimental de Partículas, Portugal
2. Efacec Electric Mobility S.A., Portugal
3. Evoleo Technologies, Portugal
4. European Space Agency (ESA), Netherlands
Dose calculations of four years RADFET response onboard ALPHASAT will be presented using a conversion function from voltage shift to dose that includes temperature-dependence. Geant 4 simulations to validate the results will be presented.

PH-7  Radiation Environment in the LHC Arc Sections during Run 2 and Future HL-LHC Operations
K. Bilko¹, C. Bahamonde Castro¹, M. Brugger¹, R. Garcia Alia¹, Y. Kadi¹, A. Lechner¹, G. Lerner¹, O. Stein¹
1. CERN, Switzerland
During the LHC operation small fractions of the beams are being continuously lost, creating mixed field radiation. Radiation environment in the arc sectors over Run 2 was analysed with the possible implications on electronic systems.

11:55  Closing Remarks
12:05  Best Student Presentation Award announcement
12:10  End of Friday Sessions
14:00  Bus departure for Technical Visits