SERESSA 2022

5th to 9th of December at CERN, Geneva

Closing Ceremony

19th International School on the Effects of Radiation on Embedded Systems for Space Applications

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SERESSA 2022 – Geneva, Switzerland

General Chairs

- Raoul VELAZCO (CNRS-TIMA, France) and Ygor AGUIAR (CERN, Switzerland)

Program Chair

- Jaime ESTELA (Spectrum Aerospace, Germany)

Local Chair

- Rubén GARCÍA ALÍA (CERN, Switzerland)

Poster Chairs

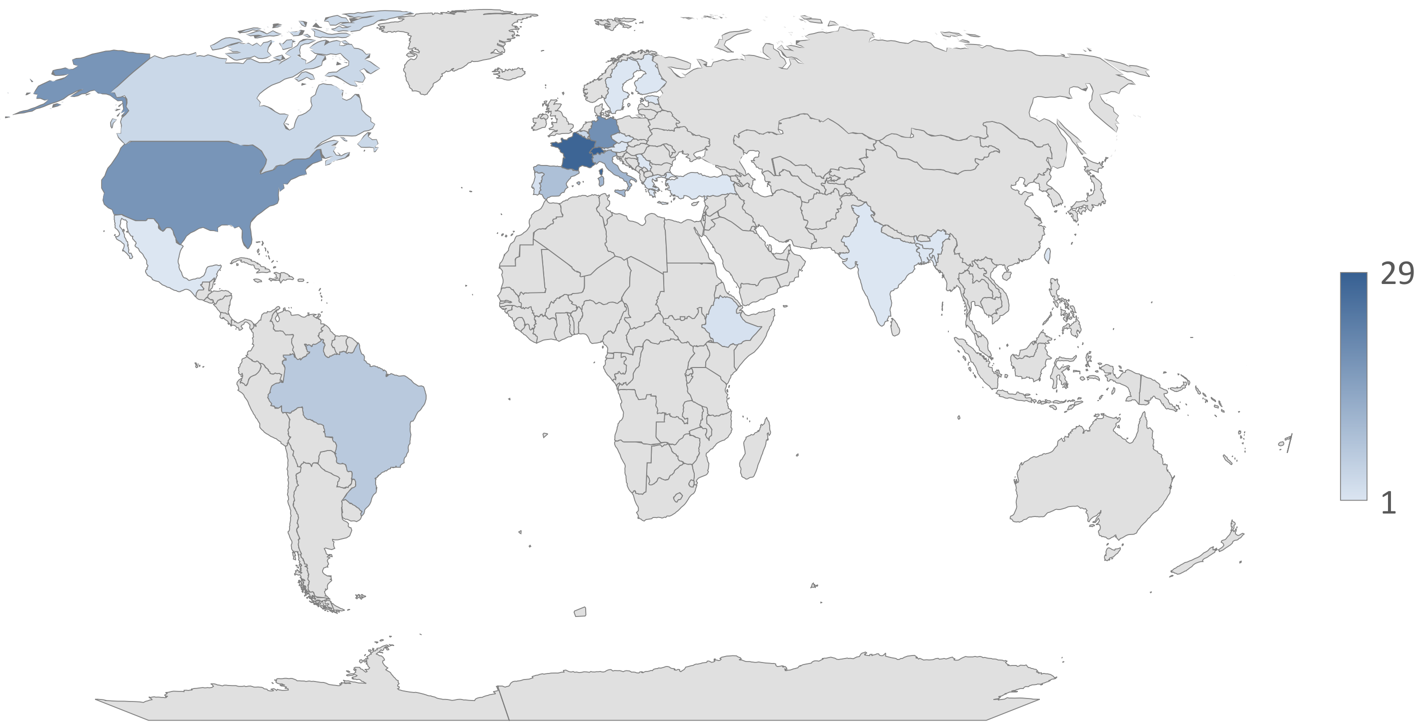
- Ygor AGUIAR (CERN, Switzerland) and Andrea CORONETTI (CERN, Switzerland)

- 24 lectures + 2 software trainings
  - USA 6, France 5, Germany 5, Switzerland 4, Italy 2, The Netherlands 1, Spain 1, Canada 1 and Brazil 1.
  - 152 attendees!

- Supported by the **CERN R2E project** and **RADNEXT European project** (Grant agreement No 101008126)

Some statistics

- Total of 152 participants
- 17% of woman
- 38% are MSc or PhD students
- 20+ countries:
  - Switzerland – 29
  - France – 28
  - Germany – 19
  - United States – 18
  - Italy – 11



Technical Program

18th International School on the Effects of Radiation on Embedded Systems for Space Applications

from **Monday, 5 December 2022 (07:30)** to **Friday, 9 December 2022 (19:00)**

Monday, 5 December 2022

08:00	**Registration**
08:30	**School Opening**
09:00	**Fundamental Mechanisms of Non-Destructive SEEs in Devices and Circuits**
09:50	**Coffee Break**
10:10	**SEE effects on VLSI devices: challenges and solutions** - Luca Sterpone
11:00	**Sensitivity characterization of SRAM-based FPGA against SEU and SET**
12:00	**Lunch break**
13:30	**TID Mechanisms in Nanometer-Scale Microelectronic Technologies** - Stefano Bonaldo (University of Padova)
14:20	**Modeling Cumulative Radiation Effects in Semiconductor Devices and Integrated Circuits** - Hugh Barnaby (ASU)
15:10	**Coffee Break**
15:30	**Error rate prediction for programmable circuits: methodology, tools and studied cases**
16:20	**Modelling and prediction of Single Event Transient and Single Event Upset** - Frédéric Wrobel

Tuesday, 6 December 2022

09:00	**Introduction to G4SEE: a toolkit for simulating radiation effects in electronics I** - David Lucsanyi (CERN)
09:50	**Coffee Break**
10:10	**Radiation Hardness Assurance (RHA)** - Stephen Buchner (Naval Research Laboratory)
11:00	**COTS in (Deep) Space** - Hans-Juergen Sedlmayr (DLR)
12:00	**Lunch break**
13:30	**Radiation Mitigation Techniques for Mixed-Signal Circuits** - Daniel Loveless (University of Tennessee Chattanooga)
14:20	**The RADNEXT irradiation facility network** - Andrea Coronetti (CERN - University of Montpellier (FR))
15:10	**Coffee Break**
15:30	**The challenges of testing COTs devices at European Irradiation Facilities**
16:20	**Fundamentals of the Pulsed-Laser Technique for Single-Event Effects Testing**

Wednesday, 7 December 2022

09:00	**Introduction to G4SEE: a toolkit for simulating radiation effects in electronics II** - David Lucsanyi (CERN)
09:50	**Coffee Break**
10:10	**The Value of "Test-As-You-Fly": Modernizing FPGA Experimentation And Data Analysis for Critical Space Missions** - Melanie Berg (Founder/CEO of Space R3 LLC)
11:10	**Radiation Hardening by Software: Advanced FDIR and Redundancy Concepts with COTS in Space**
12:00	**Lunch break**
13:30	**System-Level Design and Radiation Test Methodologies based on a novel Software-Defined Radio Architectu...**
14:20	**The Phoenix GPS Receiver for Rocket and Satellite Applications: An Example for the Successful Utilization...**
15:10	**Coffee Break**
15:30	**Single-Event Effect Criticality Analysis** - Anthony Sanders Jonathan Allen Pellish
19:00	**Social Dinner**

Thursday, 8 December 2022

09:00	**Introduction to OMERE: a tool for space environment and radiation effects on electronics devices I**
09:50	**Coffee Break**
10:10	**Accelerator Radiation Environment and Neutron Effects in Electronics** - Matteo Cecchetto (CERN)
11:00	**Introduction to 'Radiation to Materials': methodologies and examples** - Matteo Ferrari
12:00	**Lunch break**
13:30	**Analyzing data extracted from radiation tests in advanced SRAMs**
14:20	**Accurate Abstraction and High Level Modeling and Validation of SEE in Electronic Systems**
15:10	**Coffee Break**
15:30	**Poster Session**

Friday, 9 December 2022

09:00	**Introduction to OMERE: a tool for space environment and radiation effects on electronics devices II**
09:50	**Coffee Break**
10:10	**Mitigation of Soft Errors at Circuit Level** - Ricardo Reis (UFRGS)
11:00	**CELESTA project**
12:00	**Lunch break**
13:30	**Exam**
14:10	**School Closure**
14:40	**Visits to CERN installations**

Software Training

First time software trainings are provided at SERESSA

- 2-hour training sessions
- Hands-on experience

SERESSA 2022

Introduction to G4SEE:

a toolkit for simulating radiation effects in electronics

Dávid Lucsányi, CERN

Abstract:

G4SEE, a novel Geant4-based Monte Carlo simulation toolkit is being developed at CERN for the radiation effects community, and released as a free and open-source code. It has been already demonstrated and validated experimentally by measurements of inelastic energy deposition single events of monoenergetic neutrons below 20 MeV. These two hands-on lectures will give an introduction on how to use the G4SEE toolkit in simple, but real-life scenarios to simulate, analyse and better understand the nuclear physics of Single Event Effects induced by neutrons and protons in microelectronic structures.

G4SEE website: https://cern.ch/g4see

Short Bio:

Dávid Lucsányi was graduated at Budapest University of Technology and Economics (BME) in 2016 as an Applied Physicist specialised in Nuclear Technologies. He joined CERN TOTEM experiment as a Technical student to work on solid-state detector R&D, then European Space Agency (ESA) as a Young Graduate Trainee (YGT) working on the development of Pyxel astronomical imaging detector effect modelling framework. Since 2020, he is working in CERN Radiation To Electronics (R2E) project as a Fellow on Monte Carlo simulations and analyses of Single Event Effects (SEE) and development of the G4SEE simulation toolkit. In his freetime, he works for Puli Space Technologies, as the Lead Payload Scientist of the NASA prize winner PLWS lunar neutron spectrometer instrument.

Organizers:

SERESSA 2022

Introduction to OMERE:

a tool for space environment and radiation effects on electronics devices

Léo Coïc, TRAD

Abstract:

This talk introduces the OMERE freeware and its capabilities. OMERE is a tool developed by TRAD with the support of the CNES according to the need of major actors of the European space industry. It is dedicated to accurately model the space environment for earth and interplanetary missions with industry approved and up to date environment models as well as estimate its effect on electronic devices. During this talk the main capabilities of the OMERE software will be showcased and we will go through the different steps necessary to perform calculations.

Short Bio:

Léo Coïc is a radiation engineer at TRAD. He received his master's degree in Space Systems Engineering from ESTACA (France) in 2020. Focused on the effects of radiation on electronic devices, his main activities involve working on single event effects analyses for the industry and R&D studies focused on simulation and experimental characterization of single event effects sensitivity in advanced technologies.

Organizers:

Technical Visits

- On **Friday, 09/12**, from 15h to 17h.
  - to the Synchrocyclotron (SC), the first accelerator at CERN, and;
  - to ATLAS, one of the LHC experiments

Meeting point = **Reception (Building 33) at 14:50**

R2E student grant

- 5 student grants:
  - **Arijit Sengupta**, USA
  - **Saulo Alberton**, Brazil
  - **Mahammadreza Rezaei**, Spain
  - **Stefano Marinaci**, Belgium
  - **Luca Weninger**, France

- Selection Committee:
  - Dr. Rubén García Alía
  - Dr. Ygor Aguiar
  - Dr. Andrea Coronetti

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R2E

CERN R2E Student Grant

Application Deadline
September 15th, 2022.

The Radiation to Electronics (R2E) project at CERN will provide five (5) student grants to support outstanding and highly motivated students willing to enhance their knowledge in radiation effects in electronics.

To participate to the selection process, check our website:

https://indico.cern.ch/e/SERESSA2022

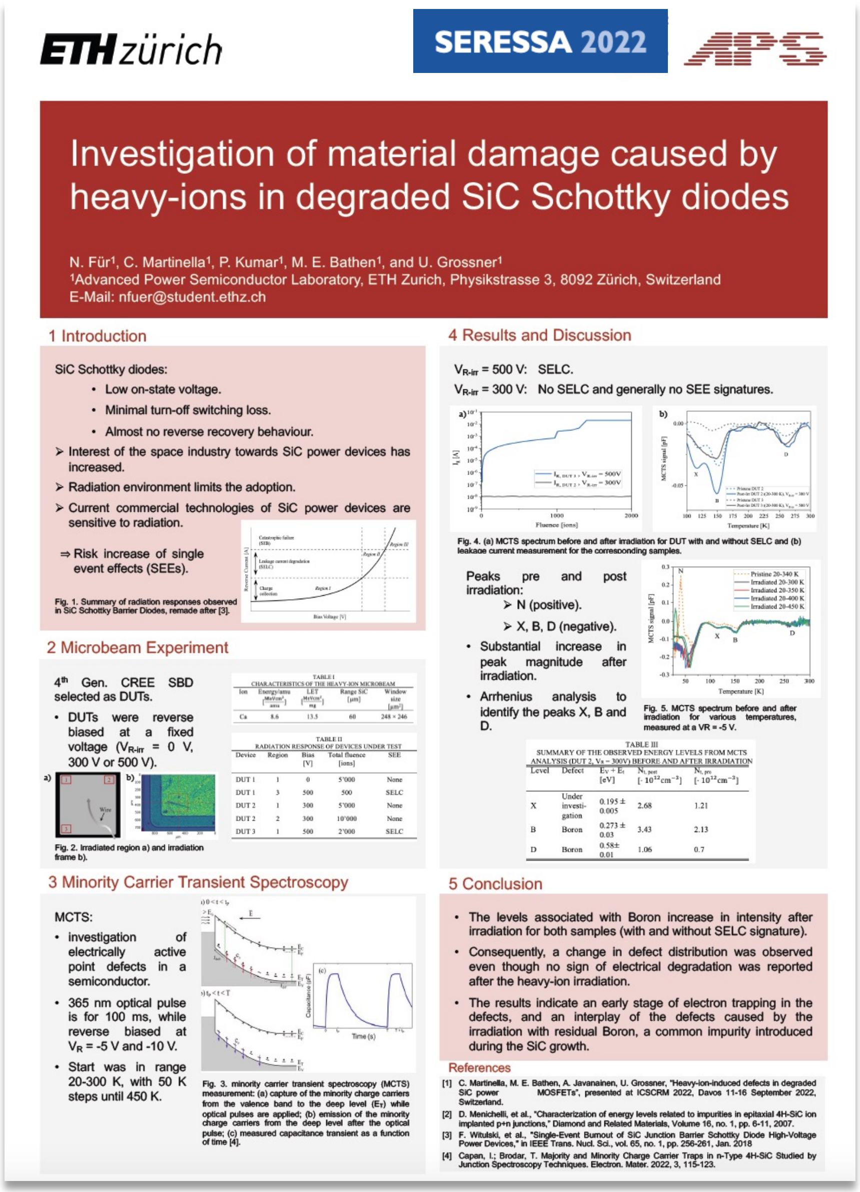
Organizers: tima, SPECTRUM AEROSPACE GROUP, CERN, RADNEXT

SERESSA Best Student Posters Award

1st Place:

Natalija Für, Corinna Martinella, Ulrike Grossner, Piyush Kumar and Marianne E. Bathen

Investigation of material damage caused by heavy-ions in degraded SiC Schottky diodes



ETH zürich SERESSA 2022 APS

Investigation of material damage caused by heavy-ions in degraded SiC Schottky diodes

N. Für[1], C. Martinella[1], P. Kumar[1], M. E. Bathen[1], and U. Grossner[1]
[1]Advanced Power Semiconductor Laboratory, ETH Zurich, Physikstrasse 3, 8092 Zürich, Switzerland
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1 Introduction

SiC Schottky diodes:
- Low on-state voltage.
- Minimal turn-off switching loss.
- Almost no reverse recovery behaviour.

➢ Interest of the space industry towards SiC power devices has increased.
➢ Radiation environment limits the adoption.
➢ Current commercial technologies of SiC power devices are sensitive to radiation.

⇒ Risk increase of single event effects (SEEs).

Fig. 1. Summary of radiation responses observed in SiC Schottky Barrier Diodes, remade after [3].

2 Microbeam Experiment

- 4th Gen. CREE SBD selected as DUTs.
- DUTs were reverse biased at a fixed voltage ($V_{R\text{-}irr}$ = 0 V, 300 V or 500 V).

Fig. 2. Irradiated region a) and irradiation frame b).

TABLE I
CHARACTERISTICS OF THE HEAVY-ION MICROBEAM

Ion	Energy/amu [MeV/cm²/amu]	LET [MeVcm²/mg]	Range SiC [μm]	Window size [μm²]
Ca	8.6	13.5	60	248 × 246

TABLE II
RADIATION RESPONSE OF DEVICES UNDER TEST

Device	Region	Bias [V]	Total fluence [ions]	SEE
DUT 1	1	0	5'000	None
DUT 1	3	500	500	SELC
DUT 2	1	300	5'000	None
DUT 2	2	300	10'000	None
DUT 3	1	500	2'000	SELC

3 Minority Carrier Transient Spectroscopy

MCTS:
- investigation of electrically active point defects in a semiconductor.
- 365 nm optical pulse is for 100 ms, while reverse biased at V_R = -5 V and -10 V.
- Start was in range 20-300 K, with 50 K steps until 450 K.

Fig. 3. minority carrier transient spectroscopy (MCTS) measurement: (a) capture of the minority charge carriers from the valence band to the deep level (E_T) while optical pulses are applied; (b) emission of the minority charge carriers from the deep level after the optical pulse; (c) measured capacitance transient as a function of time [4].

4 Results and Discussion

$V_{R\text{-}irr}$ = 500 V: SELC.
$V_{R\text{-}irr}$ = 300 V: No SELC and generally no SEE signatures.

Fig. 4. (a) MCTS spectrum before and after irradiation for DUT with and without SELC and (b) leakage current measurement for the corresponding samples.

Peaks pre and post irradiation:
➢ N (positive).
➢ X, B, D (negative).

- Substantial increase in peak magnitude after irradiation.
- Arrhenius analysis to identify the peaks X, B and D.

Fig. 5. MCTS spectrum before and after irradiation for various temperatures, measured at a VR = -5 V.

TABLE III
SUMMARY OF THE OBSERVED ENERGY LEVELS FROM MCTS ANALYSIS (DUT 2, V_R = 300V) BEFORE AND AFTER IRRADIATION

Level	Defect	$E_V + E_t$ [eV]	$N_{t,post}$ [$\cdot 10^{12} cm^{-3}$]	$N_{t,pre}$ [$\cdot 10^{12} cm^{-3}$]
X	Under investi-gation	0.195 ± 0.005	2.68	1.21
B	Boron	0.273 ± 0.03	3.43	2.13
D	Boron	0.58± 0.01	1.06	0.7

5 Conclusion

- The levels associated with Boron increase in intensity after irradiation for both samples (with and without SELC signature).
- Consequently, a change in defect distribution was observed even though no sign of electrical degradation was reported after the heavy-ion irradiation.
- The results indicate an early stage of electron trapping in the defects, and an interplay of the defects caused by the irradiation with residual Boron, a common impurity introduced during the SiC growth.

References

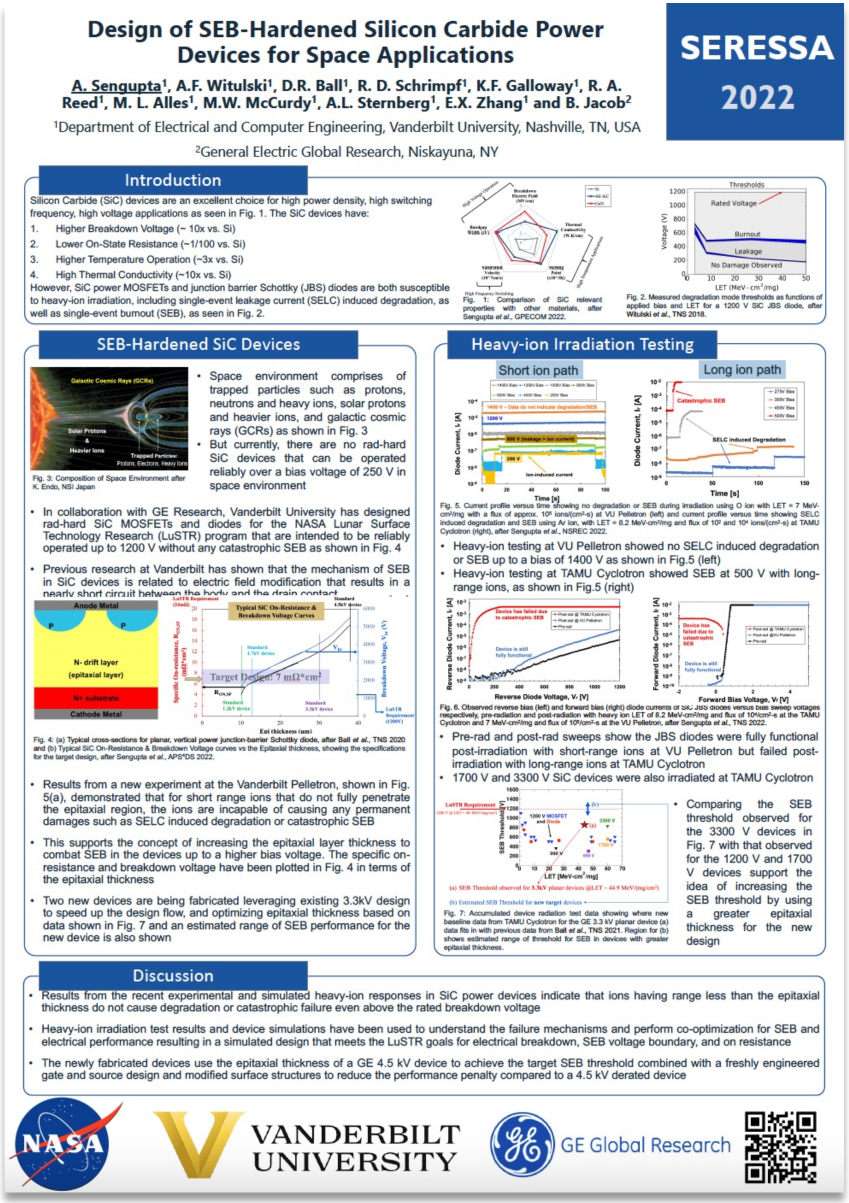
[1] C. Martinella, M. E. Bathen, A. Javanainen, U. Grossner, "Heavy-ion-induced defects in degraded SiC power MOSFETs", presented at ICSCRM 2022, Davos 11-16 September 2022, Switzerland.
[2] D. Menichelli, et al., "Characterization of energy levels related to impurities in epitaxial 4H-SiC ion implanted p+n junctions," Diamond and Related Materials, Volume 16, no. 1, pp. 6-11, 2007.
[3] F. Witulski, et al., "Single-Event Burnout of SiC Junction Barrier Schottky Diode High-Voltage Power Devices," in IEEE Trans. Nucl. Sci., vol. 65, no. 1, pp. 256-261, Jan. 2018
[4] Capan, I.; Brodar, T. Majority and Minority Charge Carrier Traps in n-Type 4H-SiC Studied by Junction Spectroscopy Techniques. Electron. Mater. 2022, 3, 115-123.

SERESSA Best Student Posters Award

2nd Place:

Arijit Sengupta, Arthur Witulski, Dennis Ball, et al.

Design of SEB-hardened Silicon Carbide Power Devices for Space Applications

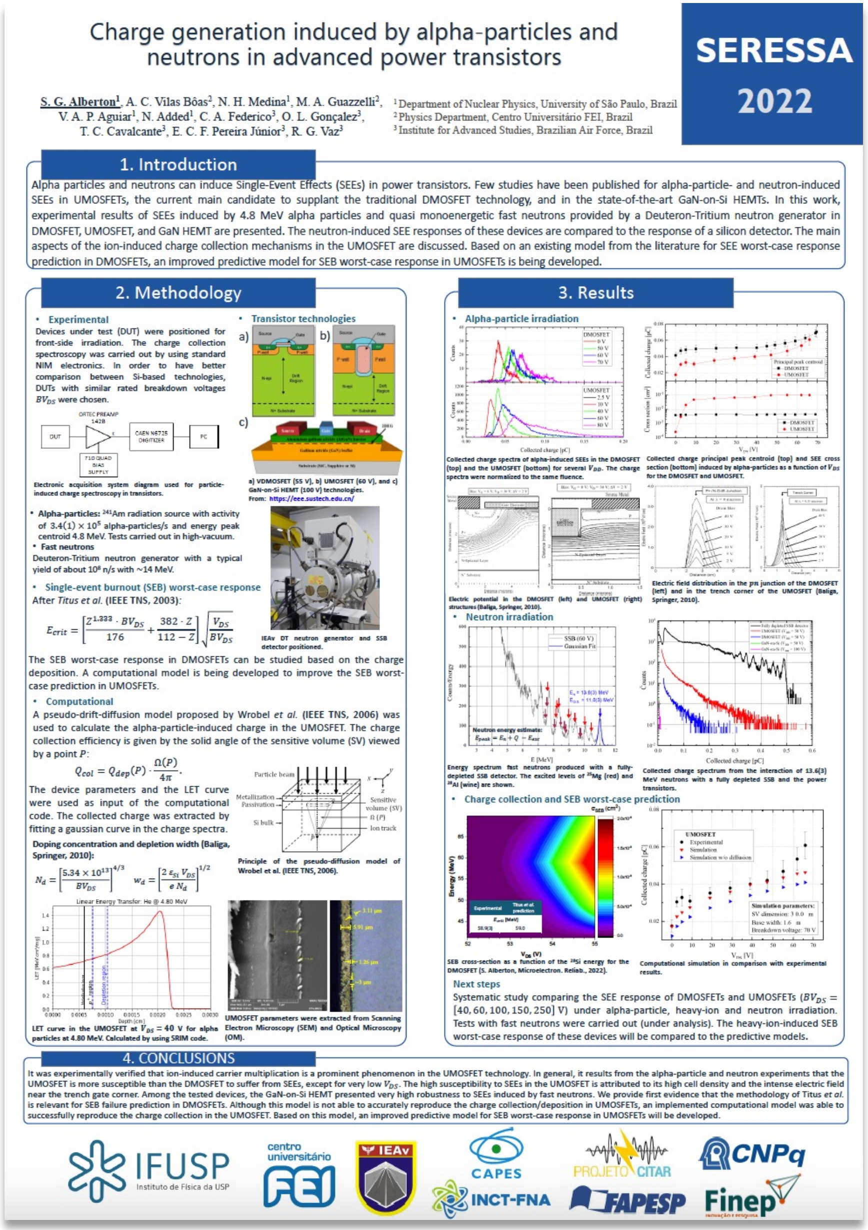


SERESSA Best Student Posters Award

3rd Place:

Saulo Alberton, Alexis Cristiano Vilas Bôas, Nilberto Heder Medina, Marcilei Aparecida Guazzelli, et al.

Charge generation induced by alpha particles and neutrons in advanced power transistors



Thank you and see you at **SERESSA** 2023!