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Use of (coupled) Monte Carlo (and electronic simulation) code to evaluate the robustness of electronic components

I Gerardy, A. Almeida Albuquerque , V. De Heyn , J. Derrien

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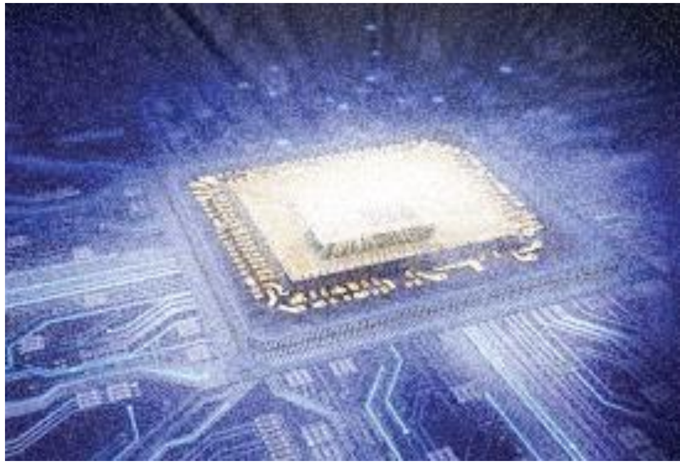
Contents

Introduction

- Electronic devices used in all daily life aspects even in place with high level of radiation (reactor, accelerator devices, deep space…)
- Interaction with ionising radiations produced free electrons
- Electrons may induced unwanted current
  - Might create extra current and disturb information transfer…
- Electron behaviour (recombination) depends on the presence of electric field within the component

Cosmic radiations and electronic components



- Electronic components are used in space industry
- Robustness have to be evaluate regarding

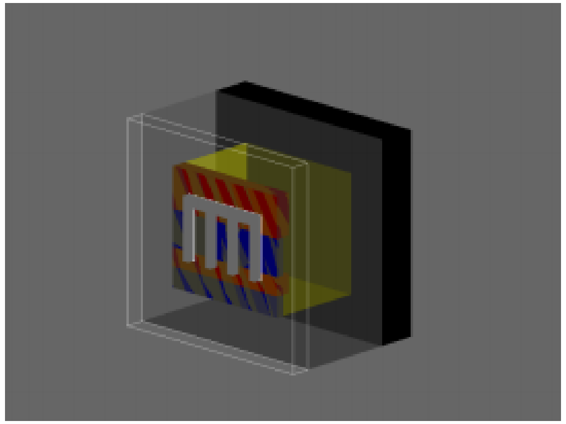
  ESA normalisation documents:
  - ESCC Basic Specification No. 22900:TOTAL DOSE STEADY-STATE IRRADIATION TEST METHOD
  - ESCC Basic Specification No. 25100:SINGLE EVENT EFFECTS TEST METHOD AND GUIDELINES
- But experimental tests require long irradiation with γ and protons at different energies
  - Expensive→ interest to use simulation codes to evaluate possible damage and predict behaviour

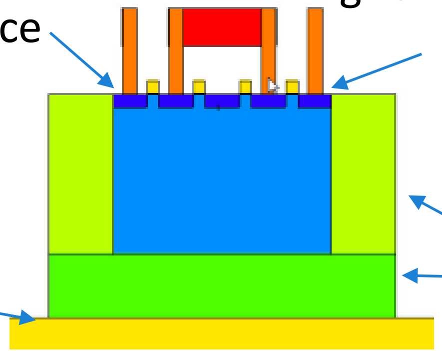
Methodology of the simulation

- Geant 4 toolkit used to evaluate the number of secondary electron produced
  - Micro-electronic physics list for protons and heavy ions
    - Protons, ^{27}Ne, ^{53}Cr, ^{124}Xe of 20, 50, 100, 150, 200 MeV
  - QBBC modular list for γ of ^{60}Co
  - Evaluation of the number of electron created in the depleted region related to
    - Type and energy of incident particles
    - Beam incidence on the target
  - Number of incident particles adapted to obtain a good statistic

Methodology of the simulation (2)

- Two types of MOSFET component
  - Solid On Insulator (SOI) technology
  - bulk technology
    - Only SOI results presented here
  - Advantage of SOI
    - Less sensitive to electronical perturbations





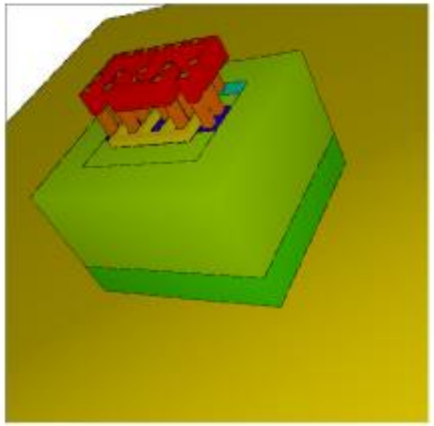
grid

source

drain

Semi conductor

insulator

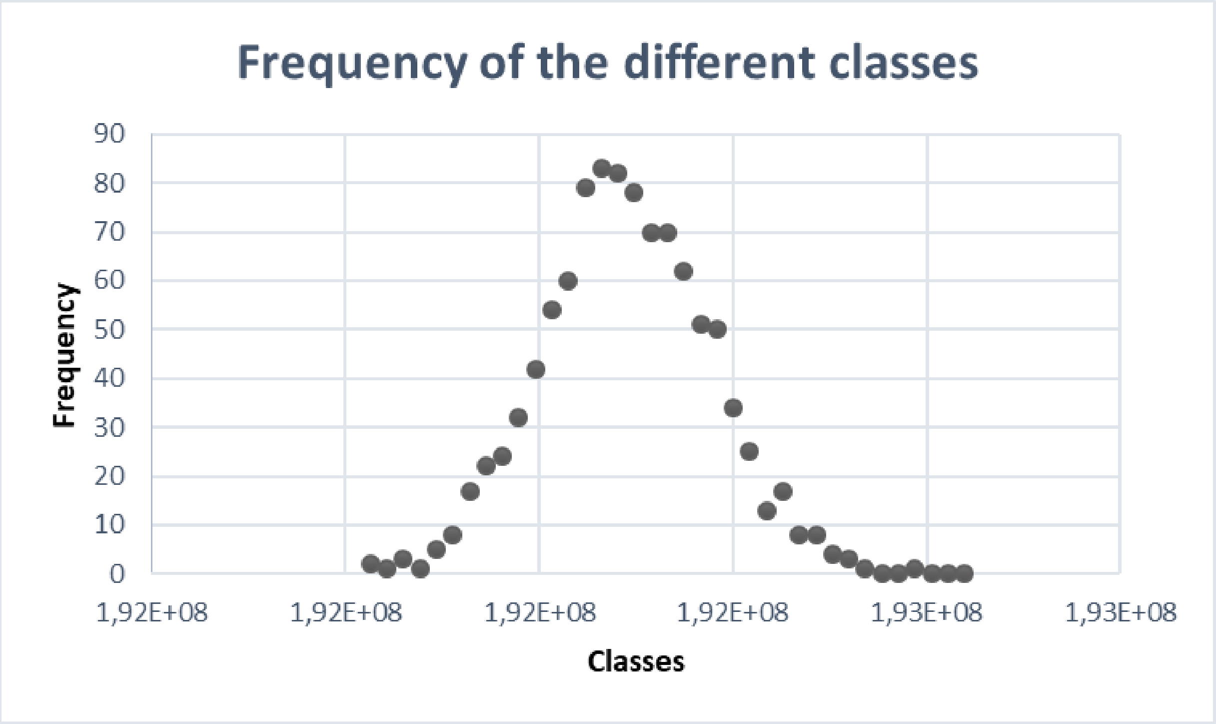


Methodology of the simulation (3)

- Statistical tests have to be written in Geant 4 code
- 8 parameters implemented
  - The mean
  - The value of standard deviation R
  - The behaviour of R
  - The stability of R
  - The variance of the variance
  - The stability of the variance of the variance
  - The behaviour of the figure of merit
  - The slope of the figure of merit

Result 1: statistical study

- 2000 simulations
- Incident proton beam of 20 MeV
- 50 million of particles
- Classes of 17.038,62 electrons
  - Mean :192353142,3
  - Std: 34493,4
  - Relative Std: 0,02%



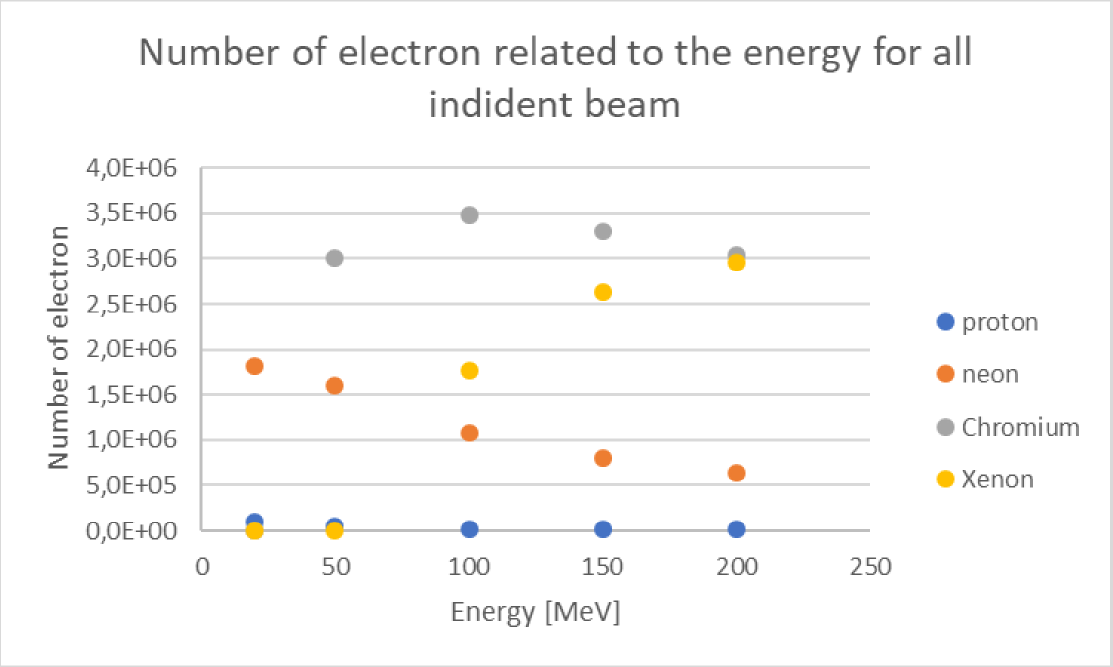
Result 2: accumulation of electrons

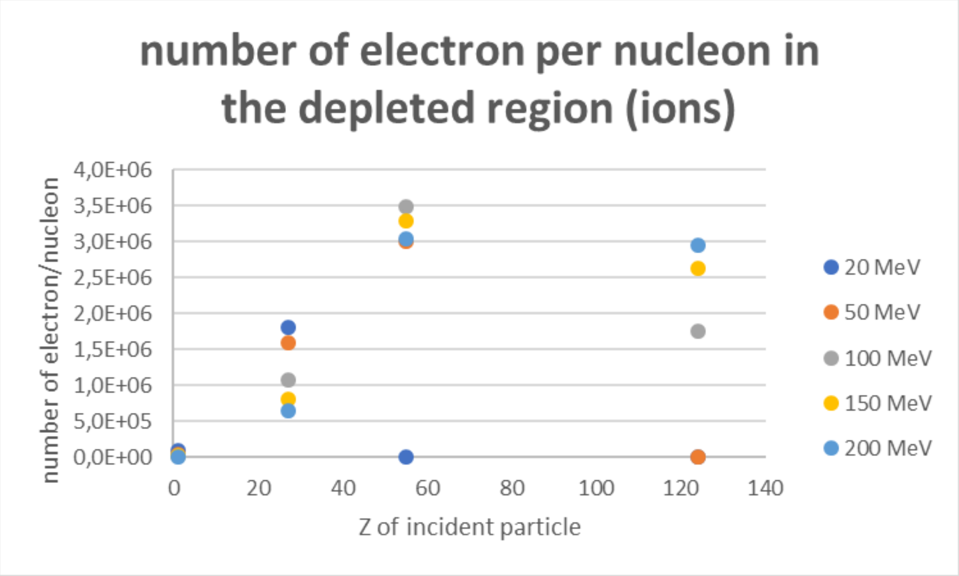
- For ^{60}Co
- In SOI type (NMOS and PMOS)

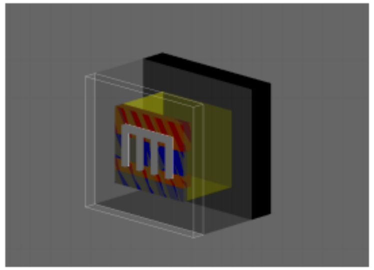
Type of transistor	Recombination without Electric field
NMOS	0.22%
PMOS	0.11%

Result 3: influence of type of particle

- For 10 million of incident particles
- For protons and heavy ions
  - Parallel beam
  - Entrance face= top of the transistor
- For ^{60}Co
  - Parallel beam
  - 2664 electrons in the depleted region

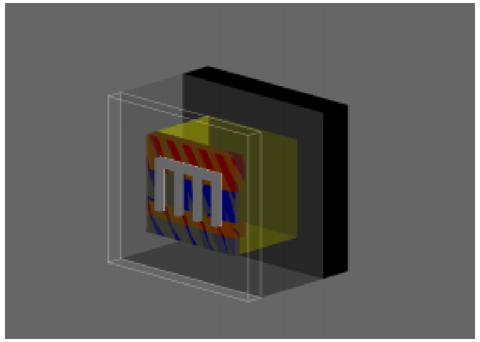


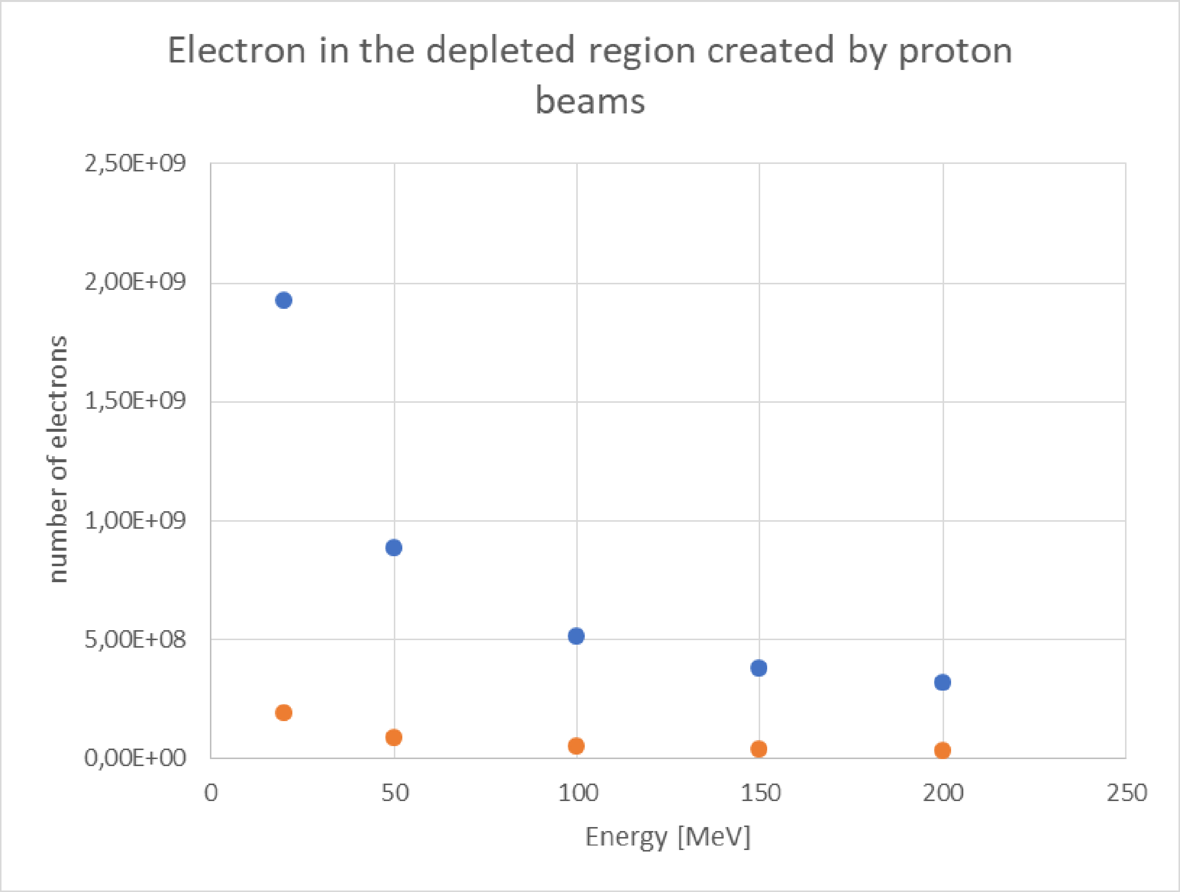




Result 4: influence of the energy and beam incidence

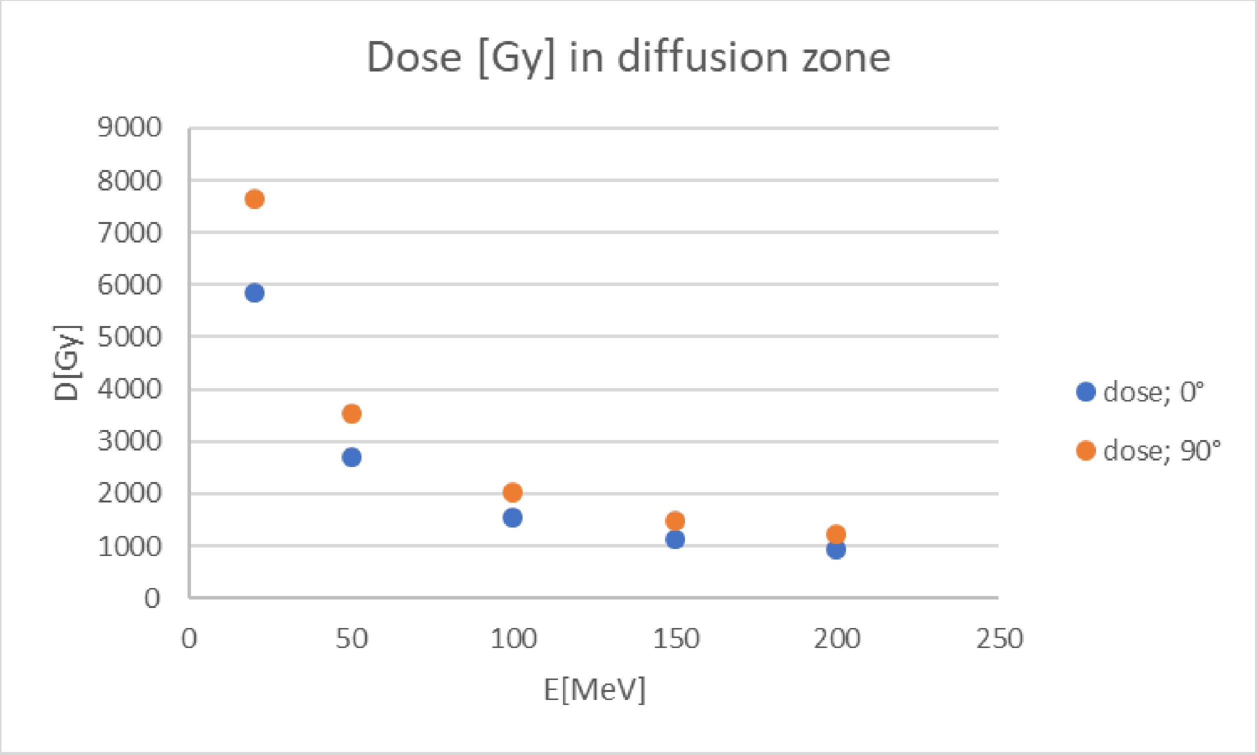
- Number of incident particles adapted to fulfil the statistical tests
- Results presented for 10 millions of particles
- Protons
- Two beam incidences
    - 0°(blue) and 90°(orange)
    - Related to top of transistor





Result 5: dose evaluation

- Following ESA recommendations
- Evaluation of the dose
  - In all diffusion zones
  - For 10 millions incident particles
  - For 2 incidences
    - 0°: particles go across all the diffusion zones of the transistor



Some comments about the results

- Model created and can be “connect” together
- Low number of recombination of electrons without electrical fields→ possible accumulation in absence of electric field: latch-up?
- Chromium of 100 MeV seems to be the most efficient in electron production in our simulations
- For protons
  - 20 MeV is the most efficient energy
  - 0° incident create more electron in depleted zone
- Dose can be evaluated and compare to the requirement of ESA

Future works

- Implement electric fields in the Geant 4 model
  - Evaluate the influence on the electron behaviour
- Coupling output of Geant4 and TCAD
  - Supplementary electrons= source for TCAD electronic simulation code
- Simulation of larger system (more than one transistor)
- Influence of the thickness of the different structures on the electron production

Acknowledgments

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  - The Walloon region who support this research by the FIRST HE program
  - nSilition who provide (confidential) information about the construction of their SOI mosfet