Adaptation of GEANT4 for Single Event Simulations


Department of Electrical Engineering & Computer Science

Vanderbilt University

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Overview

• What is GEANT4?
• Why use it?
• What is our strategy?
• How is the strategy implemented?
• What is the result?
• Summary (Current)
• What is next?
GEANT4? A Simulation Toolkit...


100 MeV protons 5 µm Si
Why use GEANT4 for radiation effects in electronics?

For an excited system, the average response, is not, in general, the response to the average excitation.

Translation: For very small devices, all events are single events.
Strategy? The Virtual Rad Lab

- Semiconductor process simulation
- Rad Effects Workbench
  Physical theory & data, symbolic computing run control
- Device & world builder
- Radiation environment models
- Virtual Irradiator: GEANT4++
- Charge & thermal deposition
- Ad hoc physical models: Tracks, RBS, multiple scattering, etc.
- Semiconductor device simulator
- CAD, etc.
Implementation? How it works...

- **VUmps (GEANT4)**
- **Geometry**
- **Events**
- **Mathematica**
- **C++ Tools, Scripting**
- **ISE TCAD (DESSIS)**
- **Automatic Meshing**
- **Gaussian charge generation**
Result: Radial Track Structure

Semiconductor process simulation
Radiation environment models
Semiconductor device simulator

Physical models: LET, NIEL, track structure, etc.

100 MeV protons in Si

Track Structure++
Result: MOS transistor response to energetic \( ? \)-ray events

Supply = 3.3 V \( R_L = 200 \) k\( \Omega \) Biased off
Drain Voltage Pulses

100 MeV protons

200 MeV protons
The largest event: $\sim 10\% V_{DS}$

Particle Trajectories
Incident proton: blue
Electrons: red

Energy in the transistor: 44.7 keV
Consistency Checks

Derivative = $R_L = 200 \text{ k}?$

Pulse shape variability!
Pulse amplitude vs. event energy

Minimum $V_{DS}$ & fit

Integrated $I_D$ & fit

Note the dispersion!
Summary

• The basic framework for ensemble simulation of single events is in place and tested.
• The methodology has been demonstrated by application to low-probability, high-energy, discrete γ-ray events.
• Development of both the overall SEE strategy and the GEANT4 libraries is ongoing.
What’s next?

- Realistic geometry
- Proton nuclear reactions
- Screened Coulomb scattering
- Heavy-ion nuclear reactions
- Validation
- Statistical studies
- Practical circuits
- Cross section

300 MeV p → 5 µm Si
? E → 18 MeV

Code: Red = e⁻; Blue = + ion; Green = n, ?, etc.