Spatial and Temporal Characteristics of Radiation-Induced Energy Deposition

A. S. Kobayashi, A. L. Sternberg,
R. D. Schrimpf, and R. A. Weller

Department of Electrical Engineering &
Computer Science

Vanderbilt University

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Overview

- Examine physically realistic extreme radiation event microstructure
- Investigate the variability and distribution of energy depositing ion strikes in silicon
- Investigate the contributions of different reaction products as an event evolves
- Demonstrate that simulation averages agree with previous works

Aaron.S.Kobayashi@vanderbilt.edu

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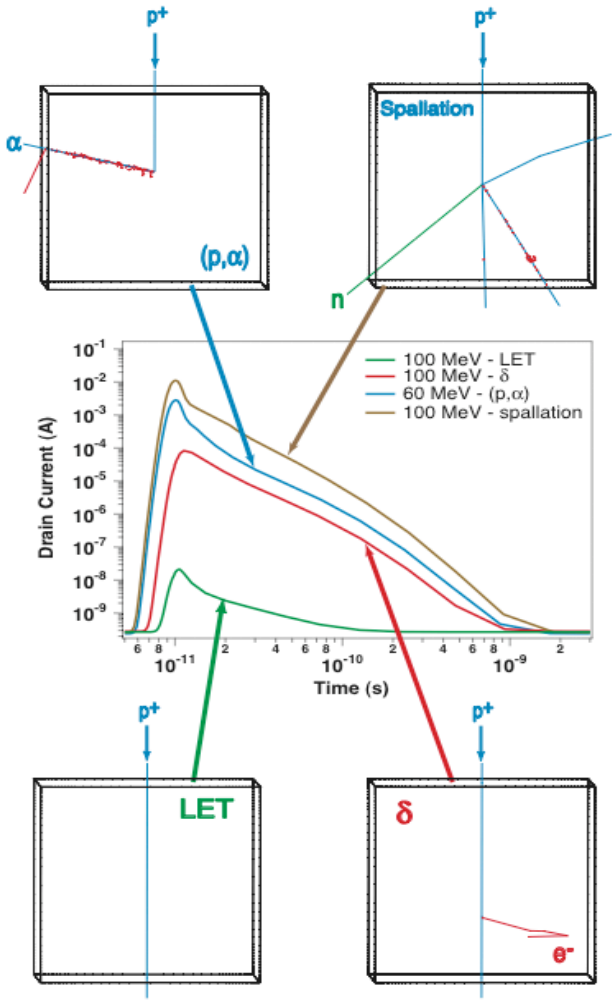
SEE Prediction with Microstructure

- Ion microstructure should be considered when performing SEE simulation
- SEE Simulation based solely on LET may not yield the worst case



Simulated drain current in a MOS transistor following ion strikes with microstructure.

After Weller et al., ITNS 50, No. 6, 2265(2003)

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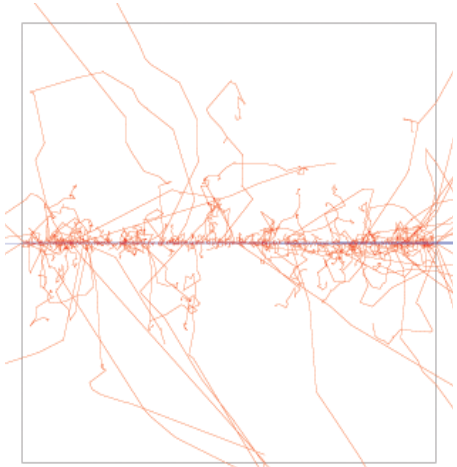
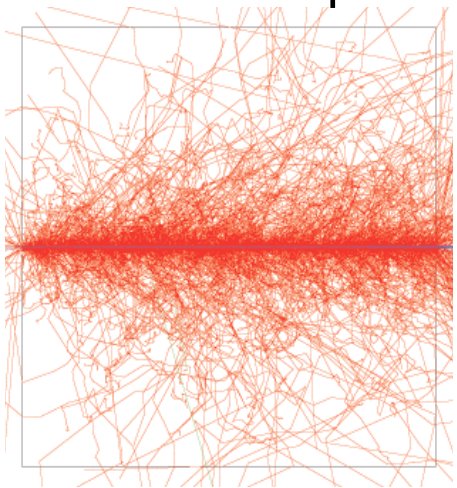
An Ensemble of Events



100 MeV p+



100 MeV α

- 1000 simulated 100 MeV ion strikes in a 6 µm cube of silicon
- Red lines represent discrete δ-rays
- Track density demonstrates LET visually
- Large degree of event variation

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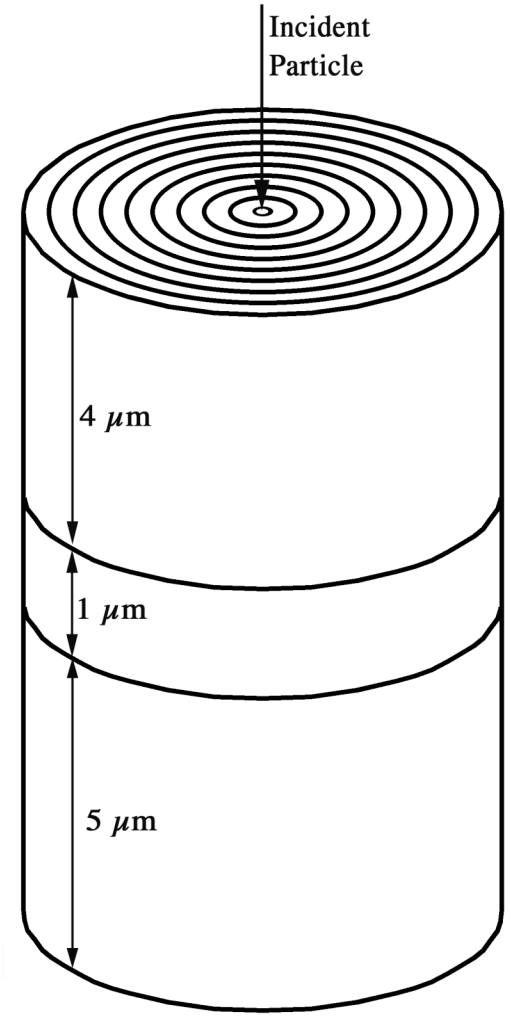
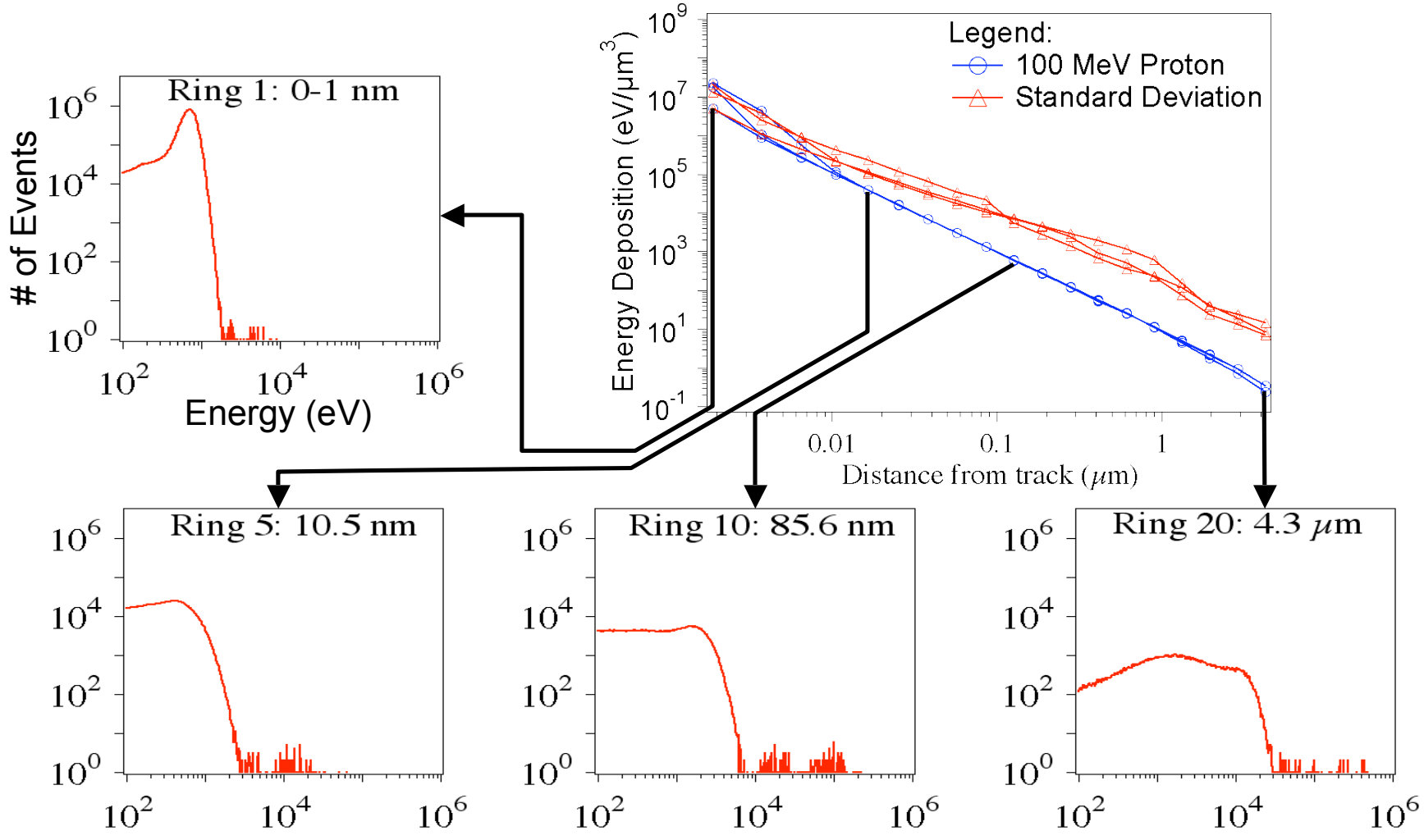
Energy Detector Setup

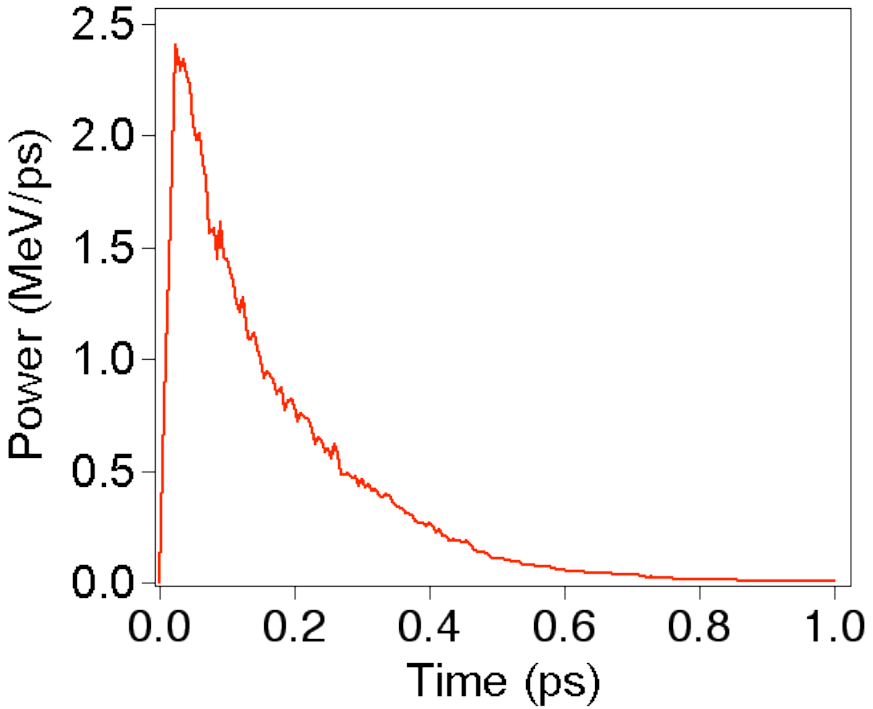
- Si cylinder with 5 μm radius
- 20 concentric shells for histogram generation
- Three layers (4 μm, 1 μm, and 5 μm thick) to eliminate potential boundary effects

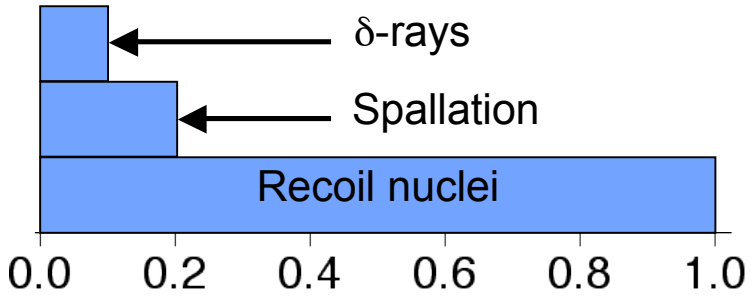


Event Variations and Distributions



Temporal Evolution





- 300 MeV protons in si
- Complete in ≈ 0.5 ps
- Results agree with P. Oldiges et al. (ITNS 47 2003)
- Discrete Ion Product Regions:
  - δ-Ray events = 0.1 ps
  - Spallation products <= 0.2 ps
  - Recoil nuclei > 0.2 ps

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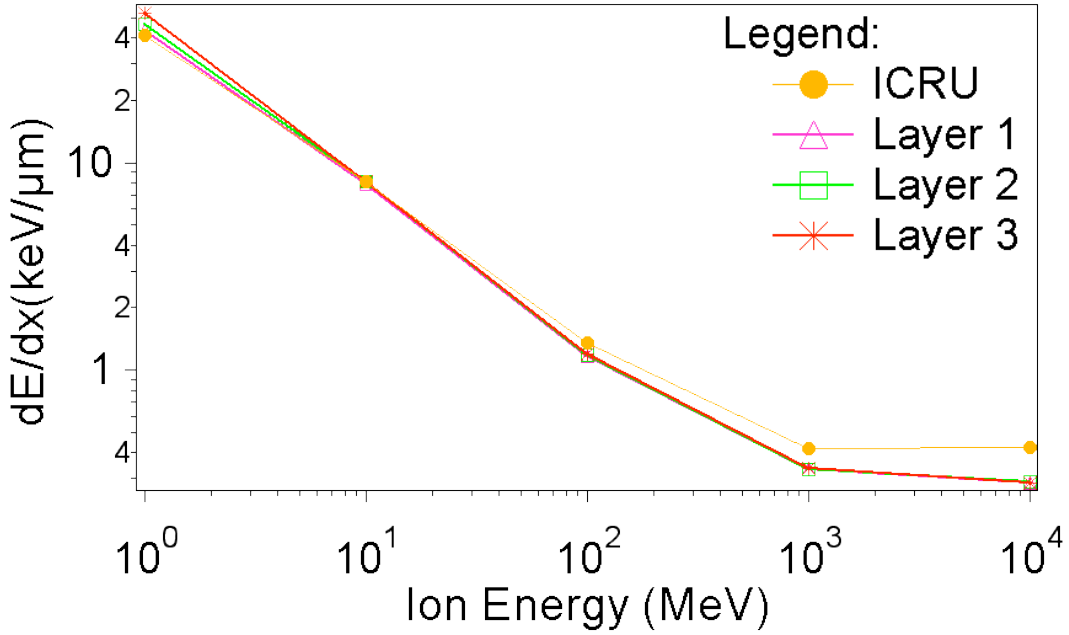
Simulator Verification



- Model includes both continuous energy loss and discreet secondary particles
- ICRU uses continuous energy loss approximation
- Average of 10^6 events agree with ICRU averages

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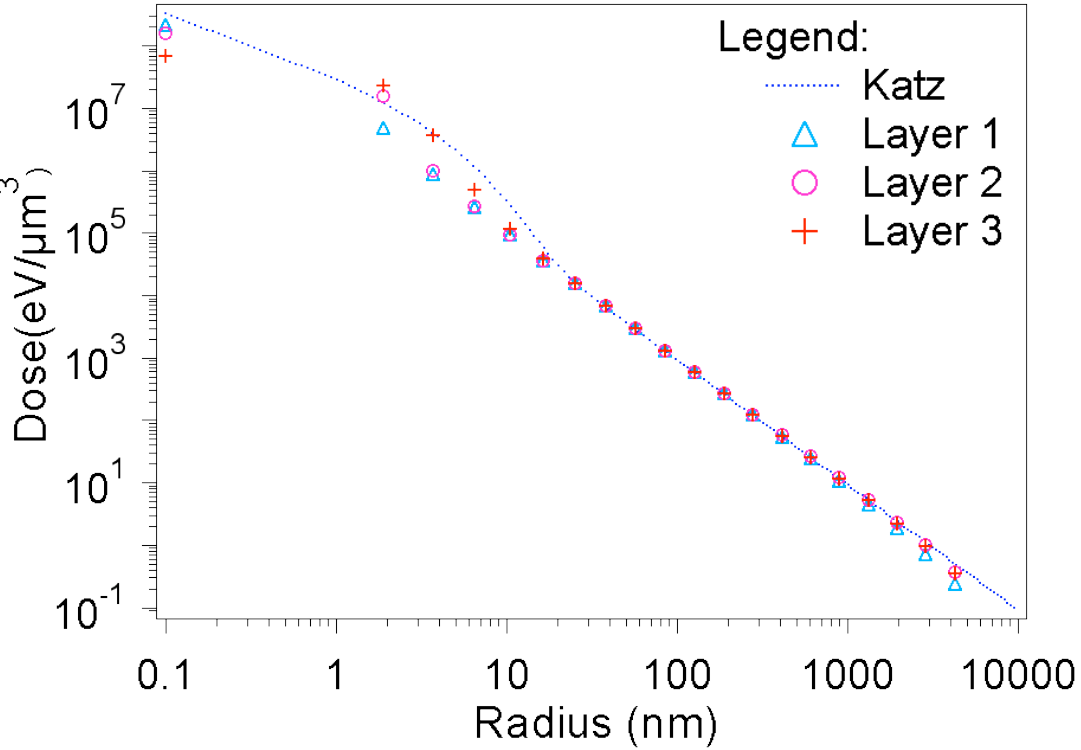
Radial Dose Comparison

- Good agreement with analytical models
- No adjustable parameters
- Microstructure and deposition profile are physically realistic



Calculated radial dose vs. an analytical model of radial dose deposition

(Waligorski et al., Nucl. Tracks 11 (1986))

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Summary

- Simulations of microstructure preserve average properties when predicting SEE
- Energy depositing events become less common but characteristically more energetic with increasing radius
- Instantaneous energy deposition is a reasonable assumption
- Future SEE simulation can account for microstructure and temporal information
- Next: Realistic Device Geometry in Simulation

Aaron.S.Kobayashi@vanderbilt.edu

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