Overview: Physically-Based Simulation of Single Event Effects

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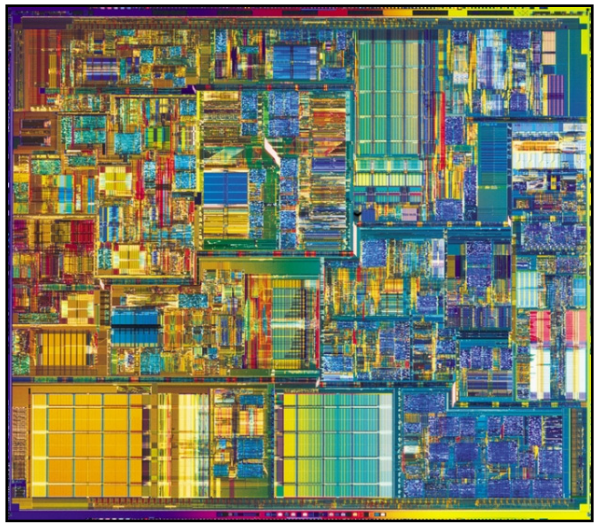
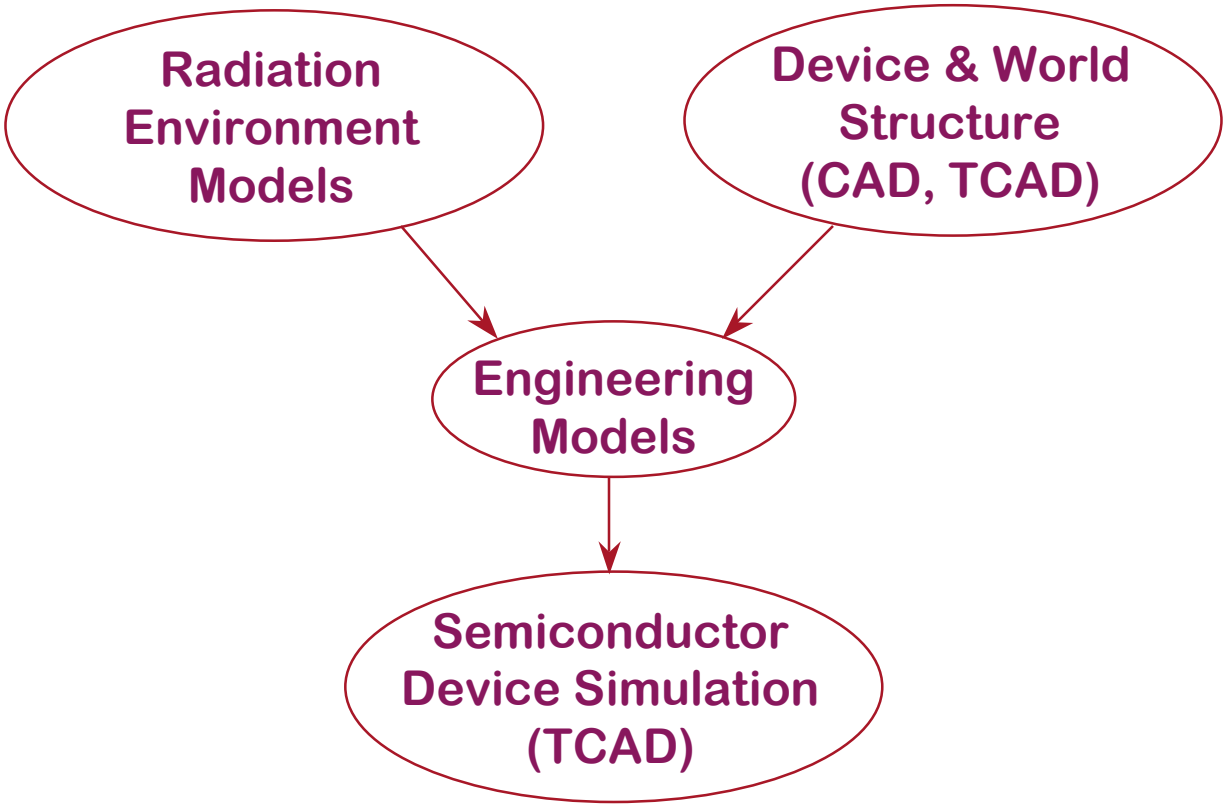
http://www.f22-raptor.com/

http://www.pbs.org/wgbh/buildingbig/



http://www.icknowledge.com/trends/p4(2).jpg

Physically-Based SEE Simulation



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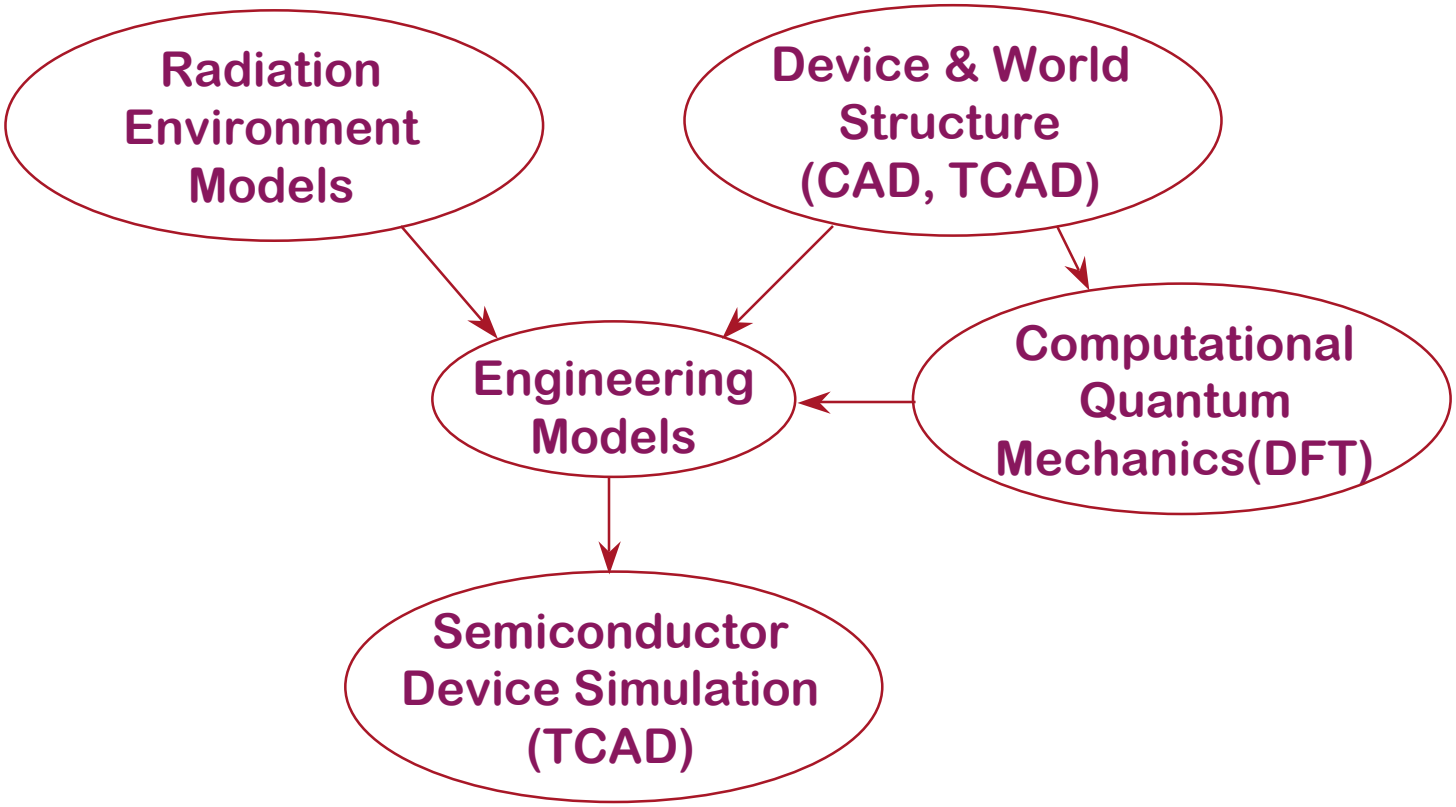

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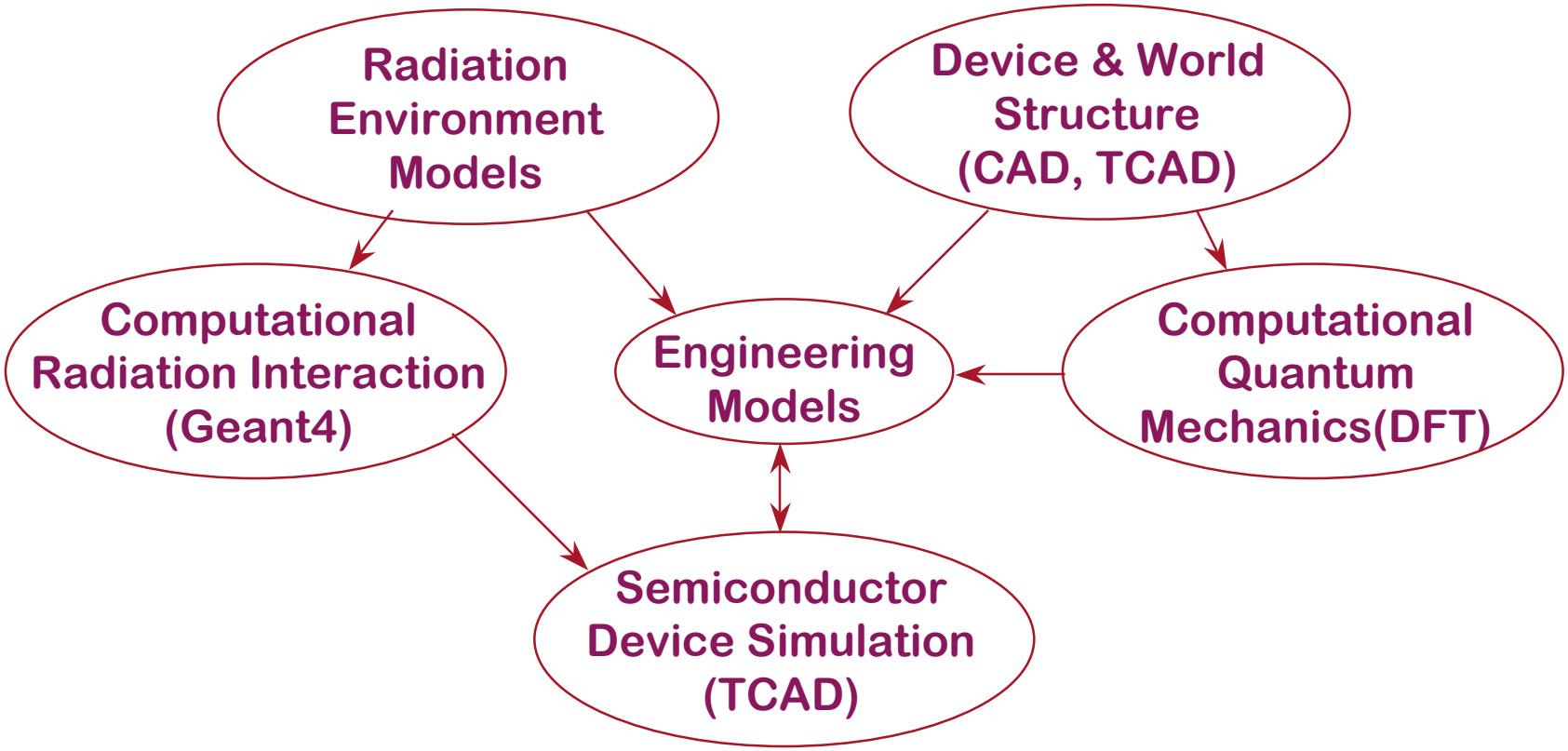
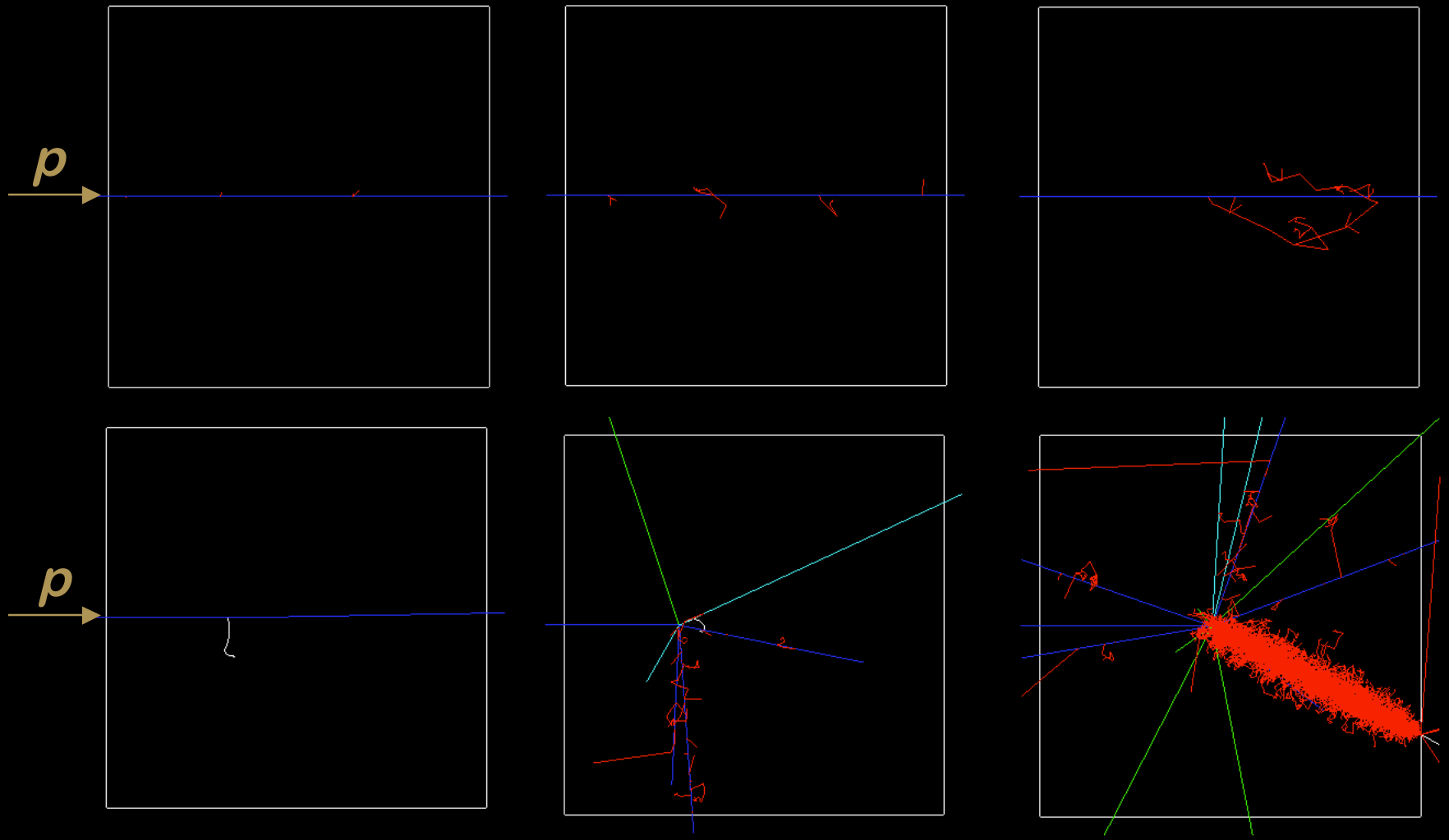


Overview

- What is our strategy?
- What is GEANT4?
- Why use it?
- How is the strategy implemented?
- What are the results so far?
  - Delta electron single events.
  - Displacement single events.
- What is next?

GEANT4? A Simulation Toolkit…

S. Agostinelli et al. "Geant4 – a simulation toolkit, " Nucl. Instr. Meth. A506 (2003) 250.



100 MeV protons →5 μm Si

Why use GEANT4 for radiation effects in electronics?

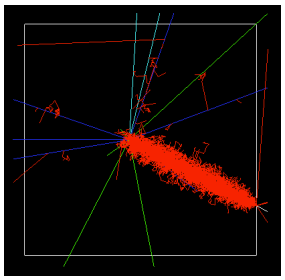
For an excited system, the average response, is not, in general, the response to the average excitation.

Translation: For very small devices, all events are *single* events.

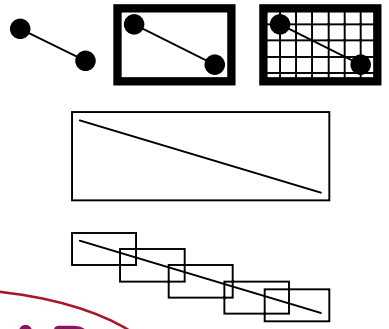
Implementation? How it works…

VUmps (GEANT4)

Events



Automatic Meshing

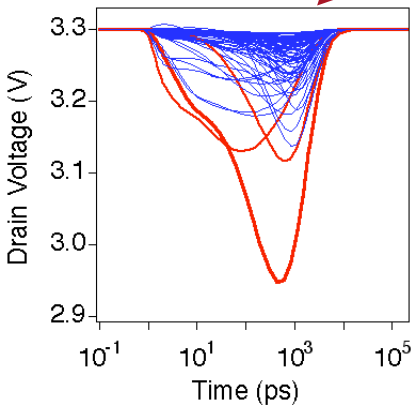


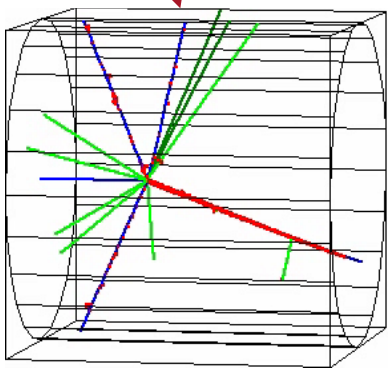
C++ Tools, Scripting

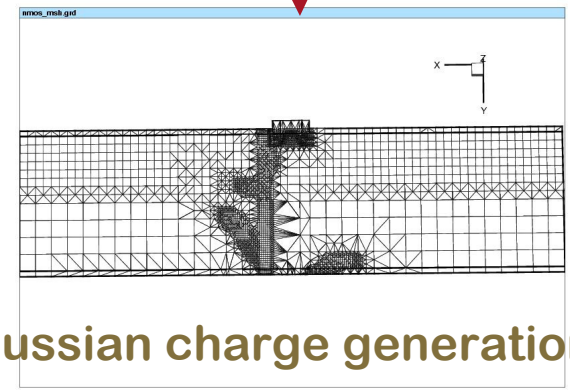
Geometry

Mathematica & Python

ISE TCAD (DESSIS)



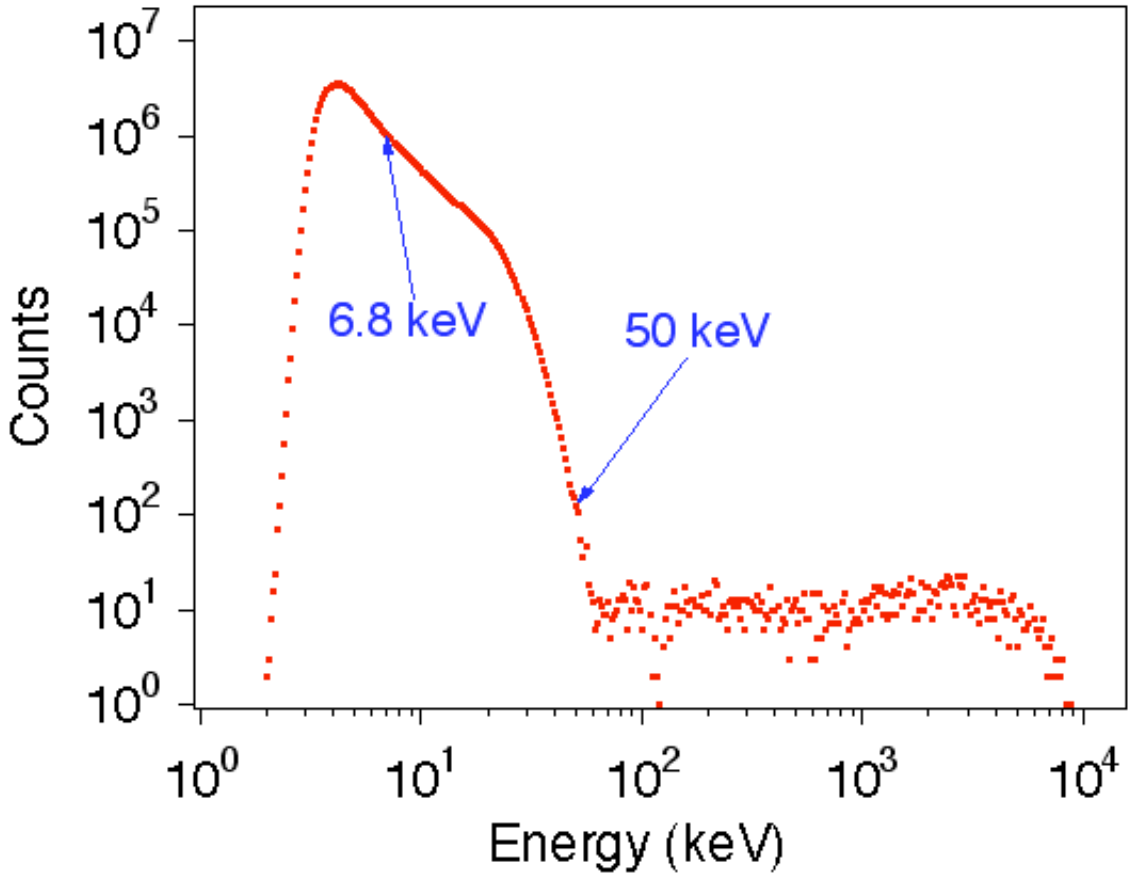


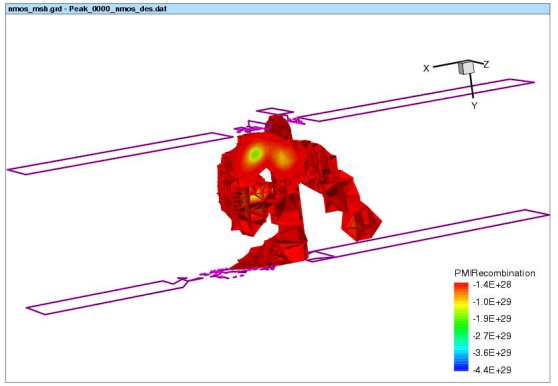


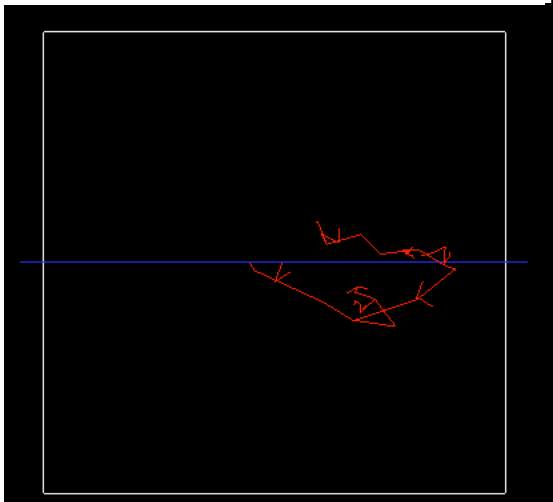
Gaussian charge generation

Result: MOS transistor response to energetic δ-ray events

Supply = 3.3 V R_L = 200 kΩ Biased off

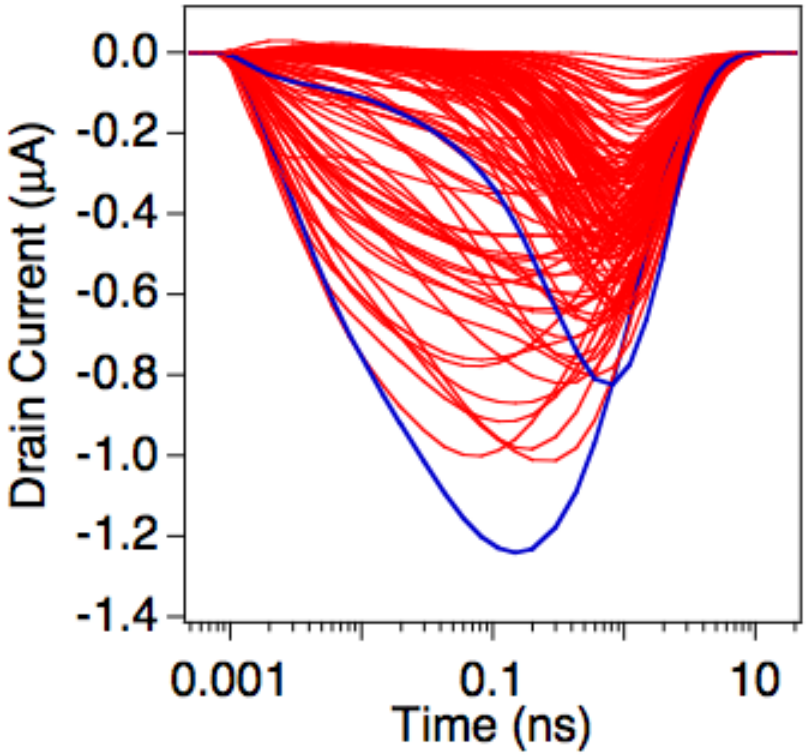




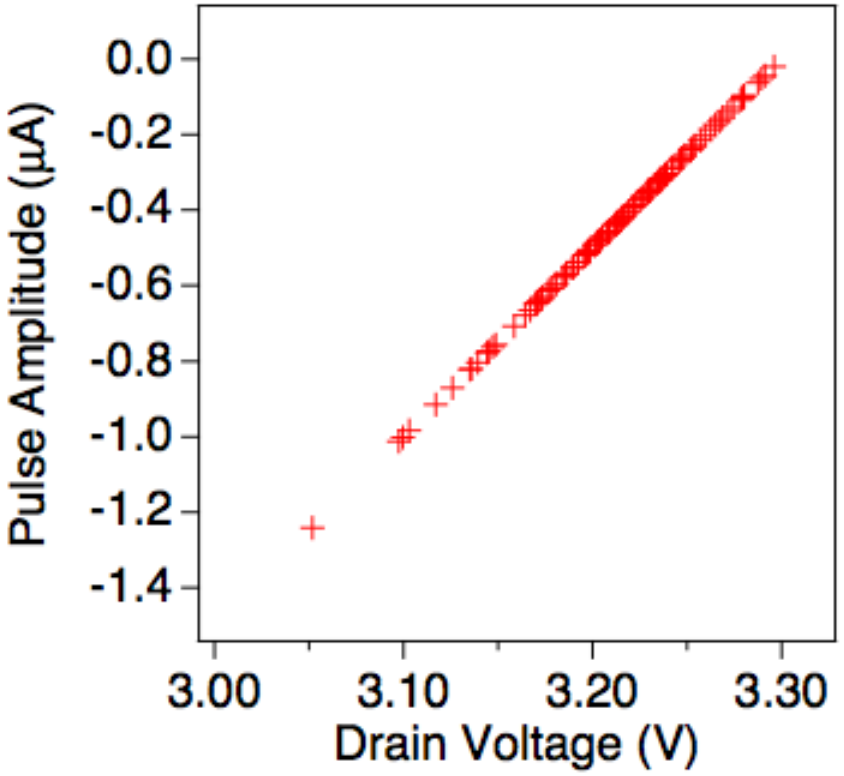


Drain Current Pulses

100 MeV protons

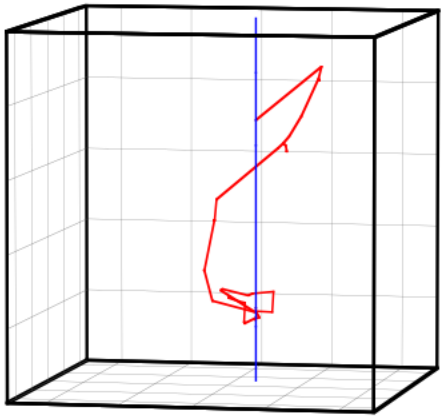


Load line = R_L = 200 kΩ

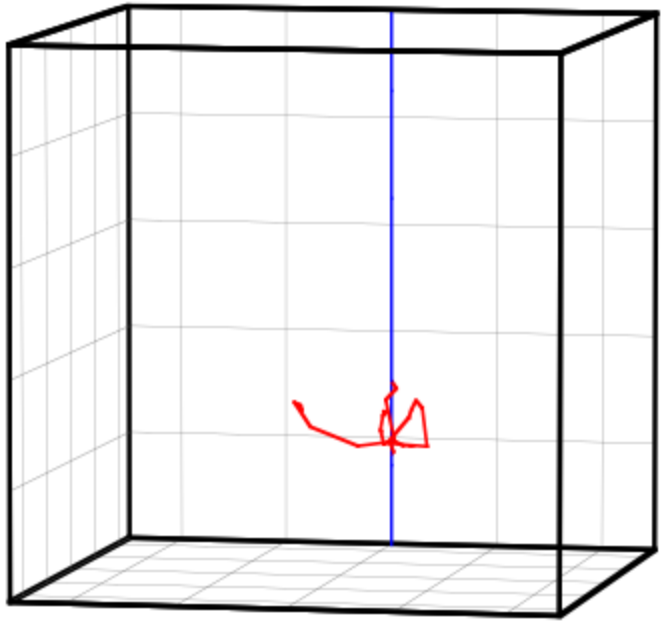


The Shape of Large-Pulse Events

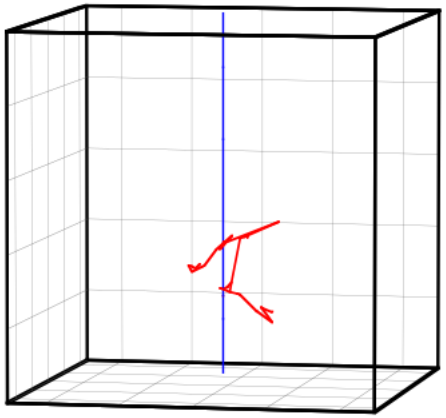
Most energetic event: 48.7 keV



35.8 keV
1.0 μA

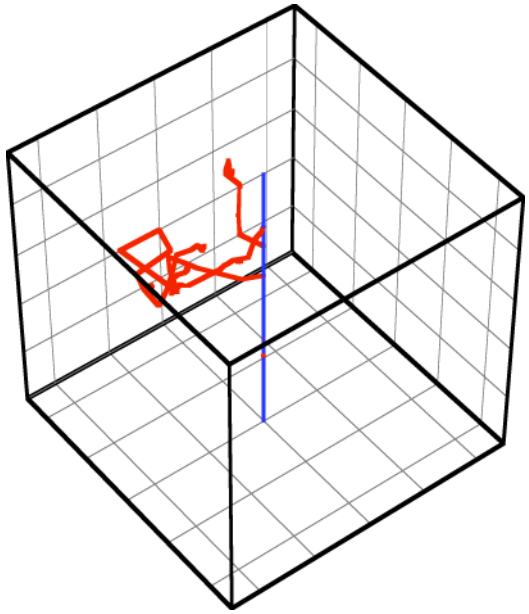


37.6 keV
1.2 μA

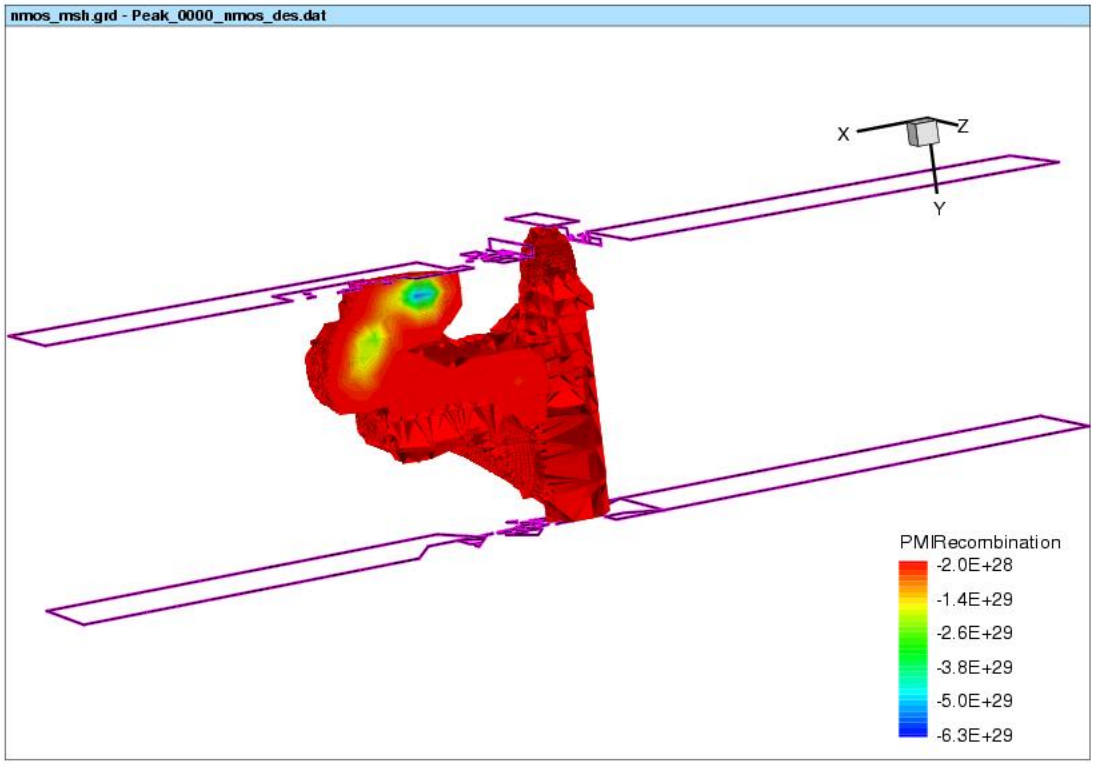


41.3 keV
1.0 μA

A large event : ≈10% V_{DS}



Particle Trajectories
Incident proton: blue
Electrons: red



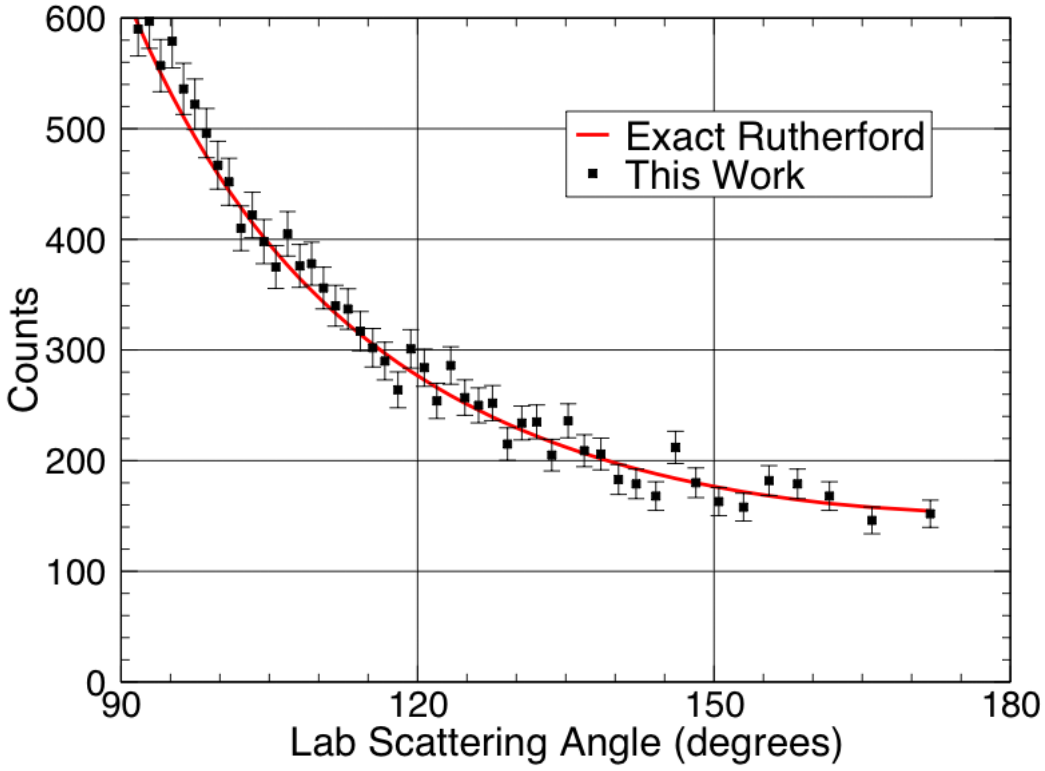
Energy in the transistor: 44.7 keV

Result: A displacement damage module for Geant4

- Objective: Add screened Coulomb scattering to Geant4
- Why?
- Incorporate TRIM/SRIM functionality
- Compute nonionizing energy deposition to estimate displacement damage
- Low priority for Geant4 collaboration

Validation: Rutherford Scattering

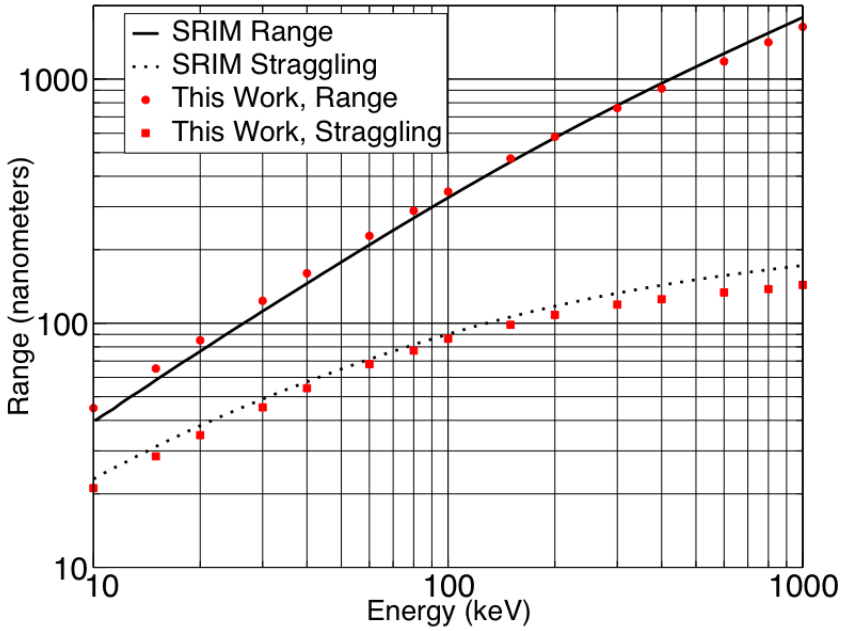
2 MeV α paraticles on 100 nm of Si



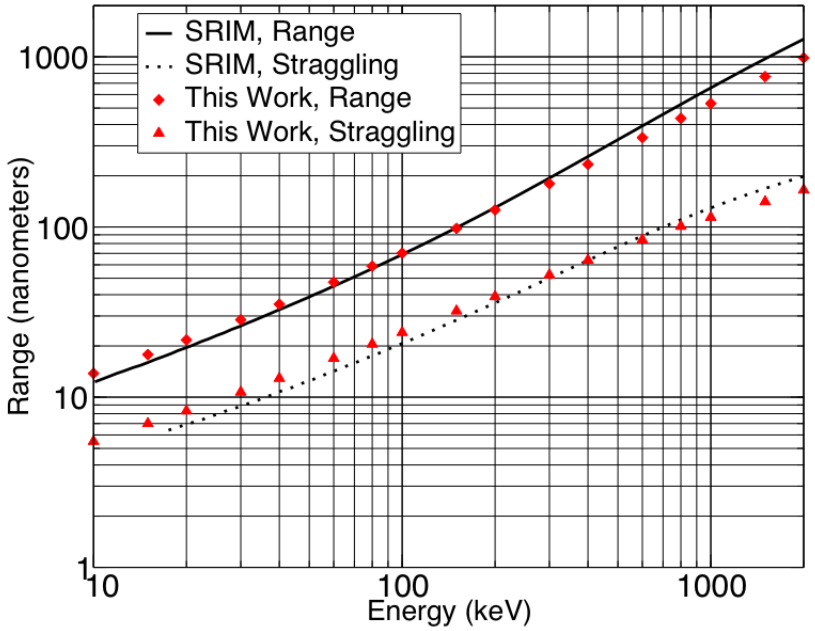
Conclusion: Large angle scattering is correct

Validation: Ion Implantation

Boron in Si



Arsenic in Si

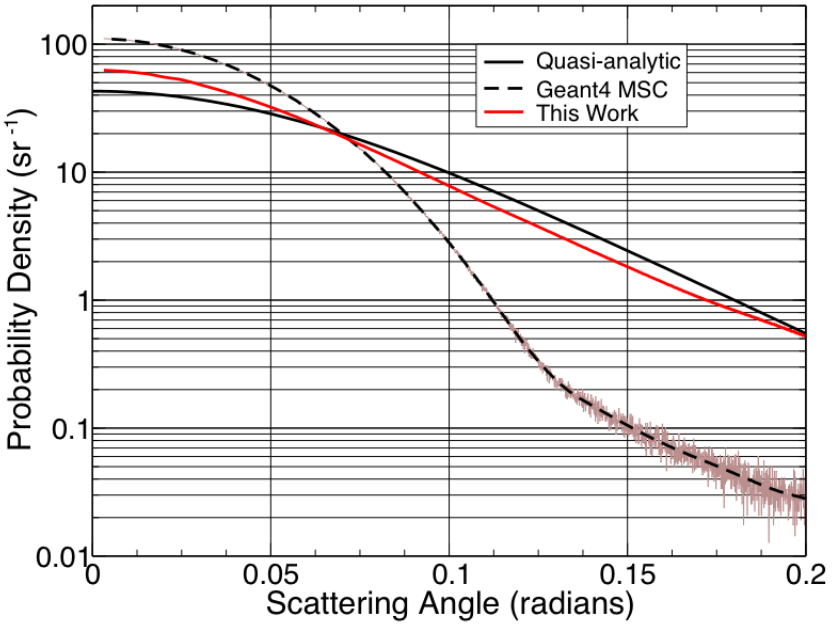


Conclusion: Energy deposition processes are correct

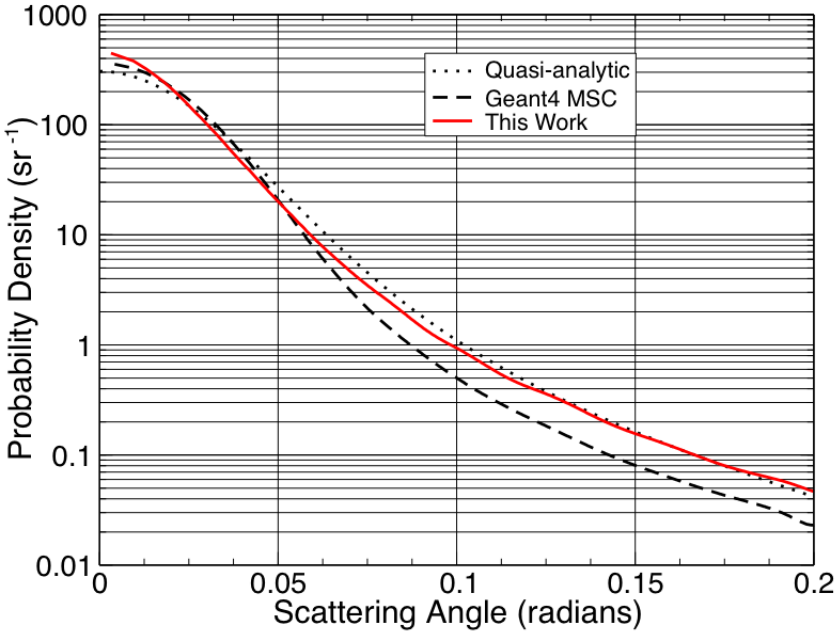
Validation: Multiple Scattering

270 keV projectiles on 100 μg/cm^2 of C

α particles

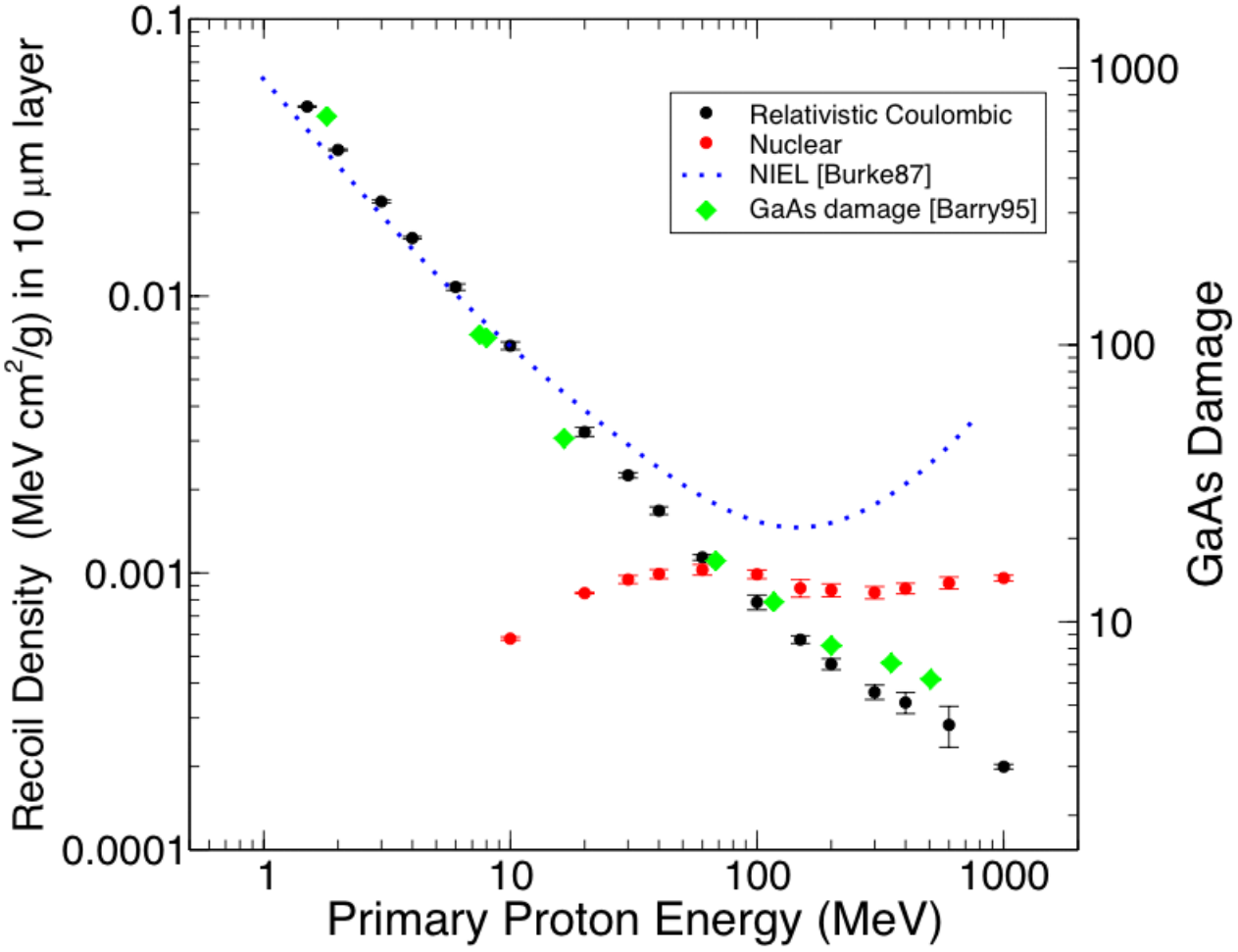


Protons

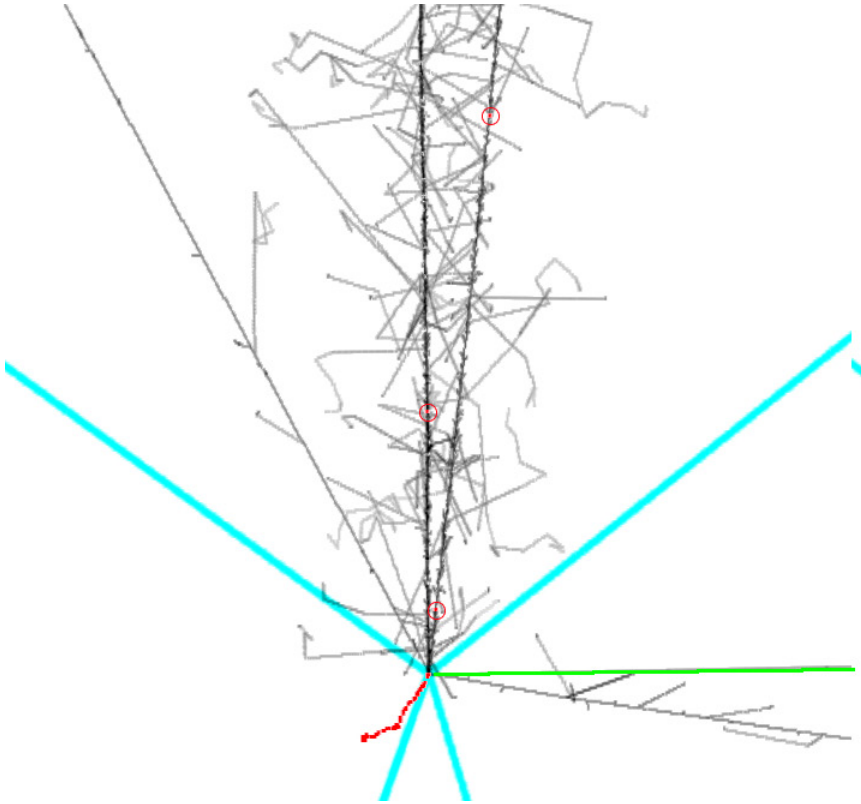


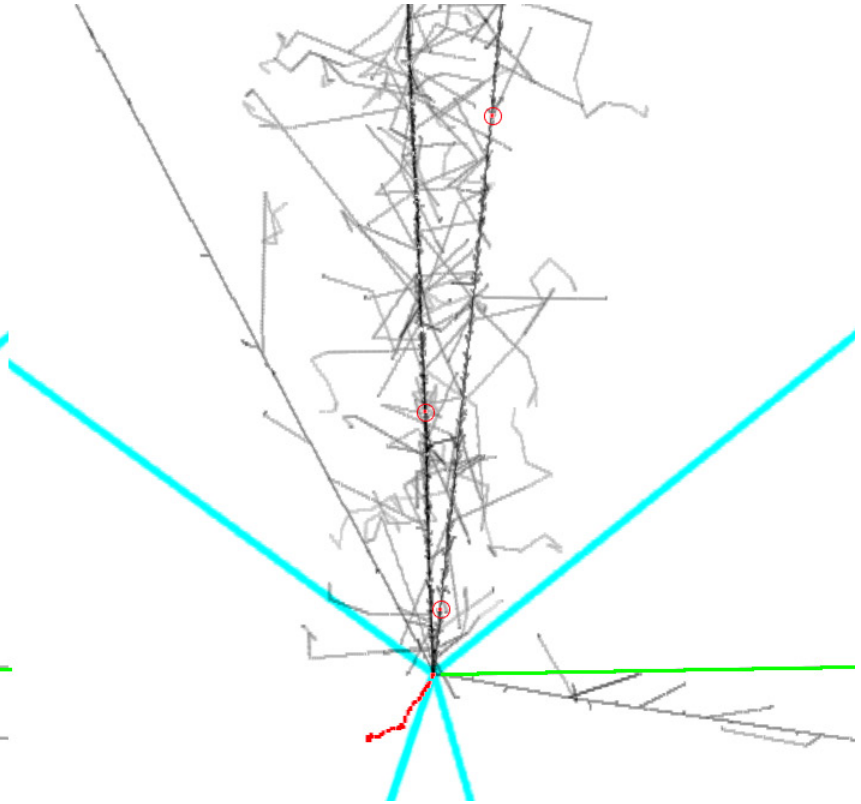
Conclusion: Small-angle collisions are correct

Displacement Damage in GaAs

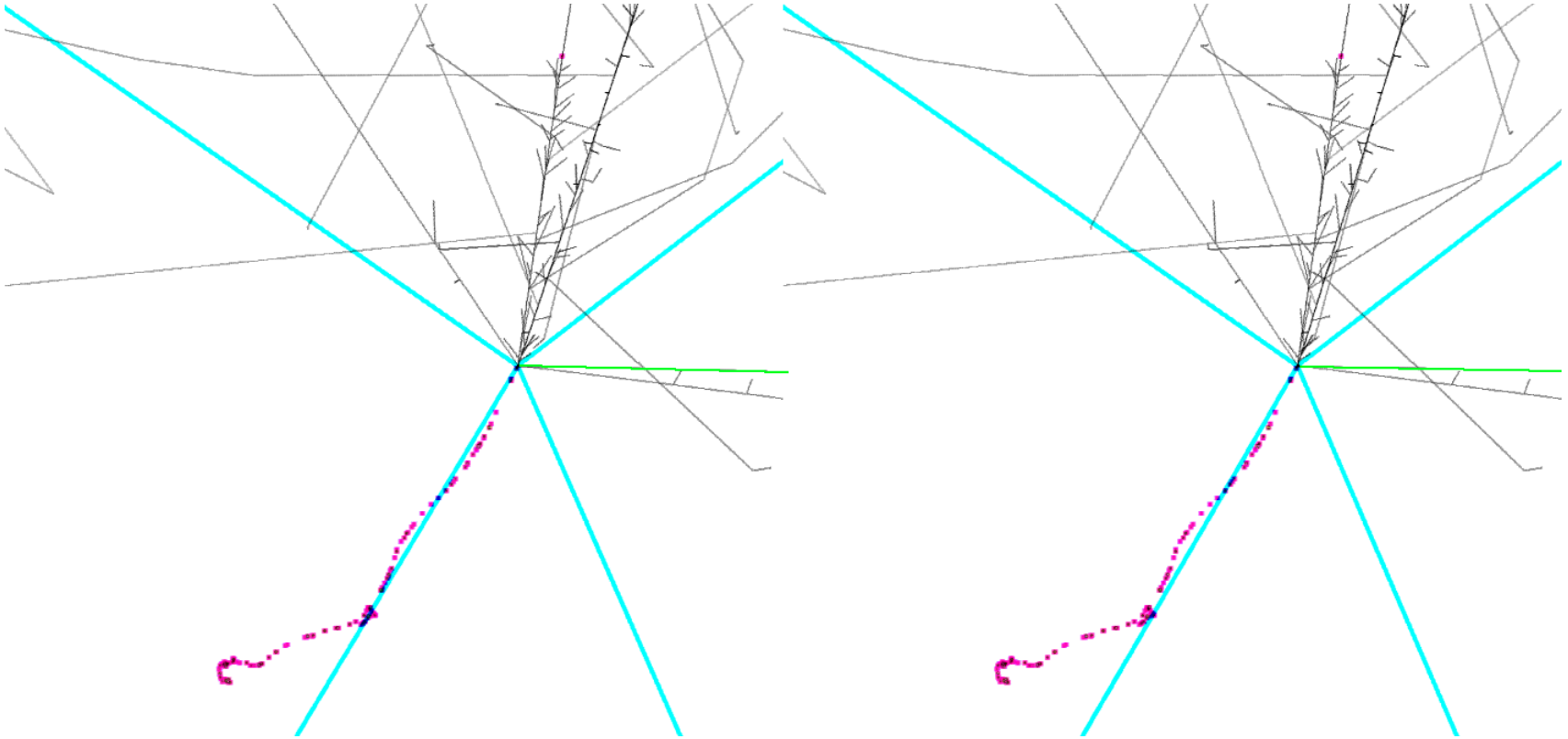


Viewing Displacement Damage



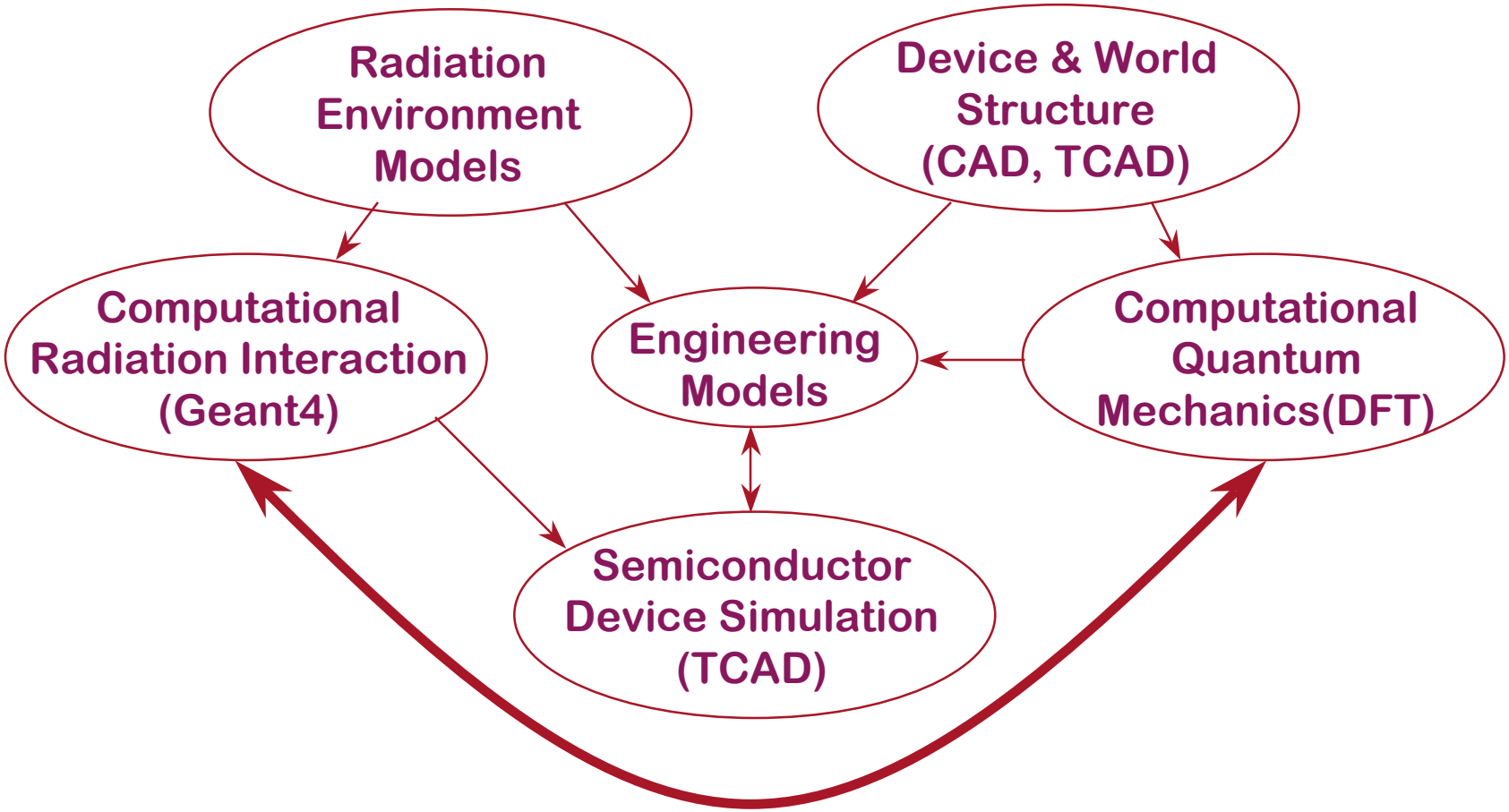


A Displacement Single Event



How does energy translate to electrical activity?

Physically-Based SEE Simulation



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 δ-ray events.
- A screened Coulomb scattering module has been written and tested for displacement damage computations.
- Our first event tool for rectangular samples is begins testing this week…

What's next?

- Incorporate realistic device geometry
- Simulate proton, heavy-ion nuclear reactions
- Develop SEE cross section estimates
- Compute systematic nonionizing energy values
- Analyze devices - small, new technologies
- Couple energy deposition/defect theory
- Develop derivative models, software engineering
- *Validation, validation, validation!*

^{56}Fe on Si: 56 GeV