MRED

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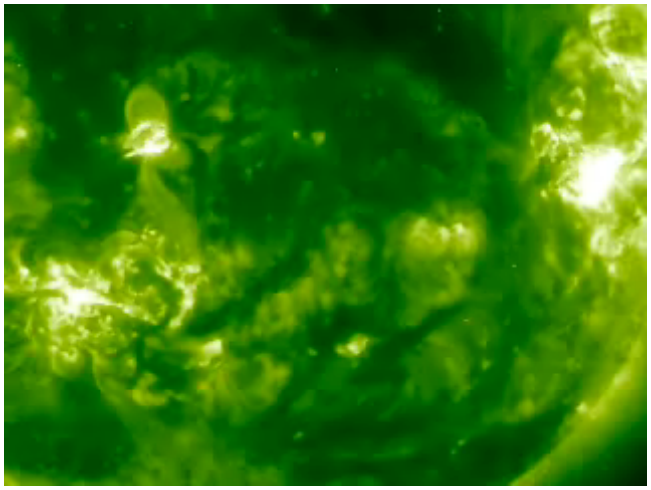
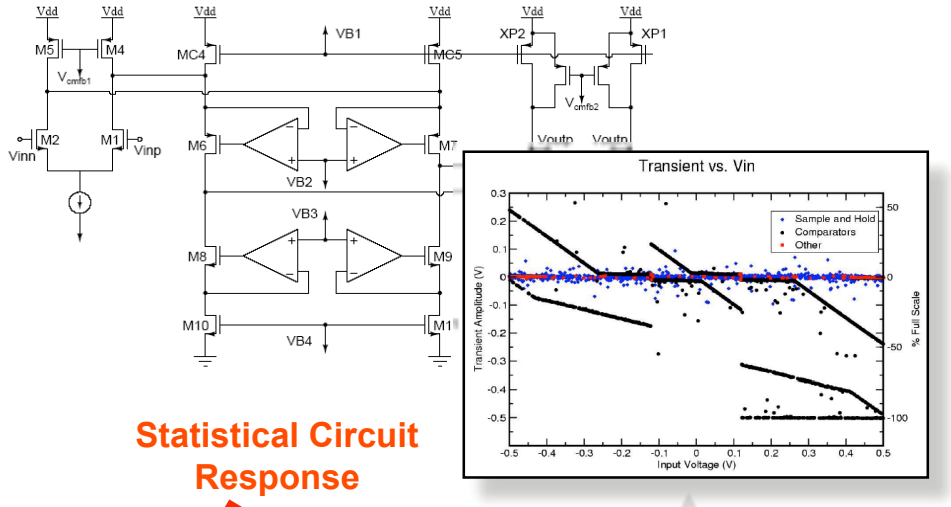
Sponsoring Agencies: NASA, DTRA, AFOSR

NASA Review — 15/Nov/2007

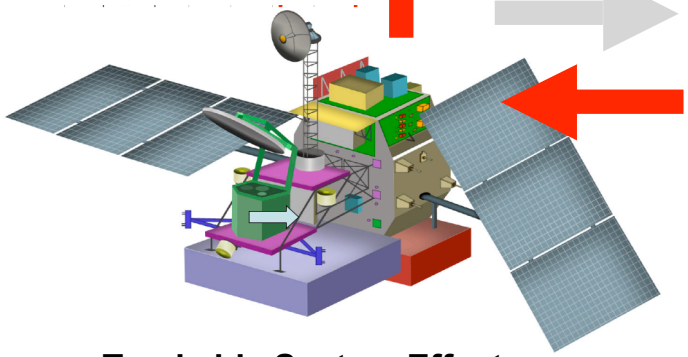
First-Principles Rad Effects Analysis



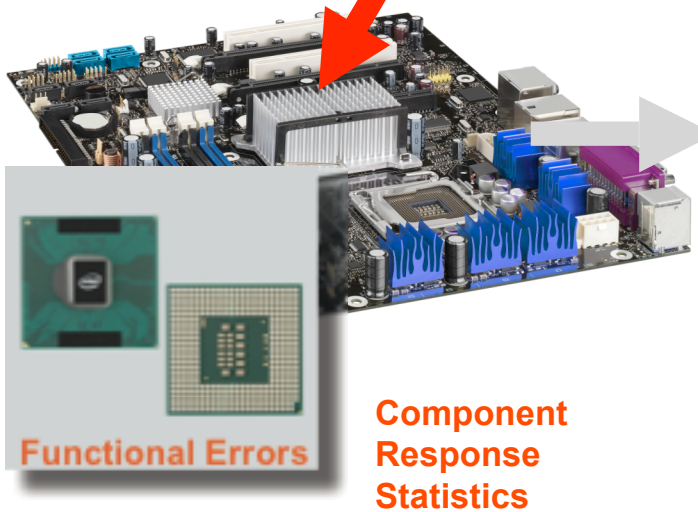
Predictable System Error Rates



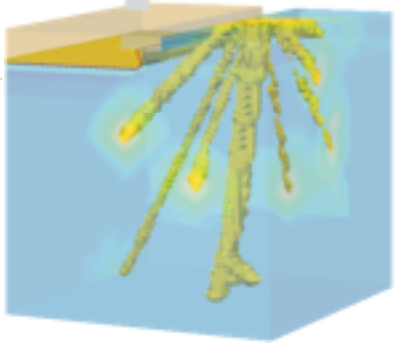
Statistical Circuit Response



Trackable System Effects

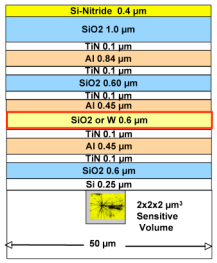
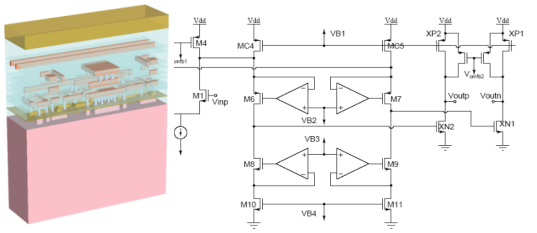
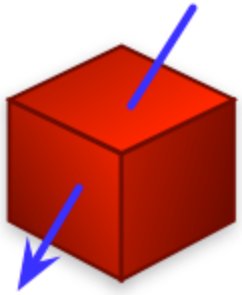
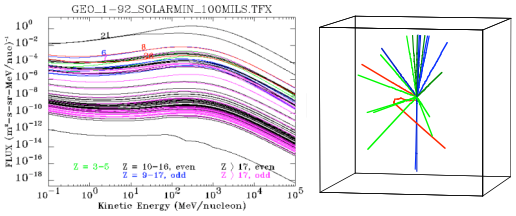
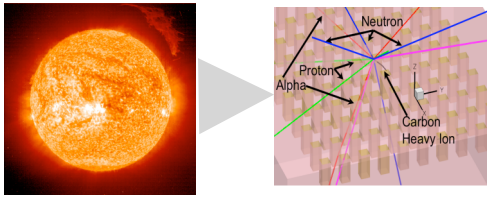
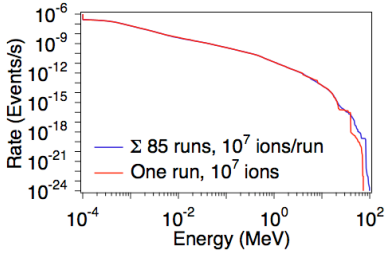


Component Response Statistics

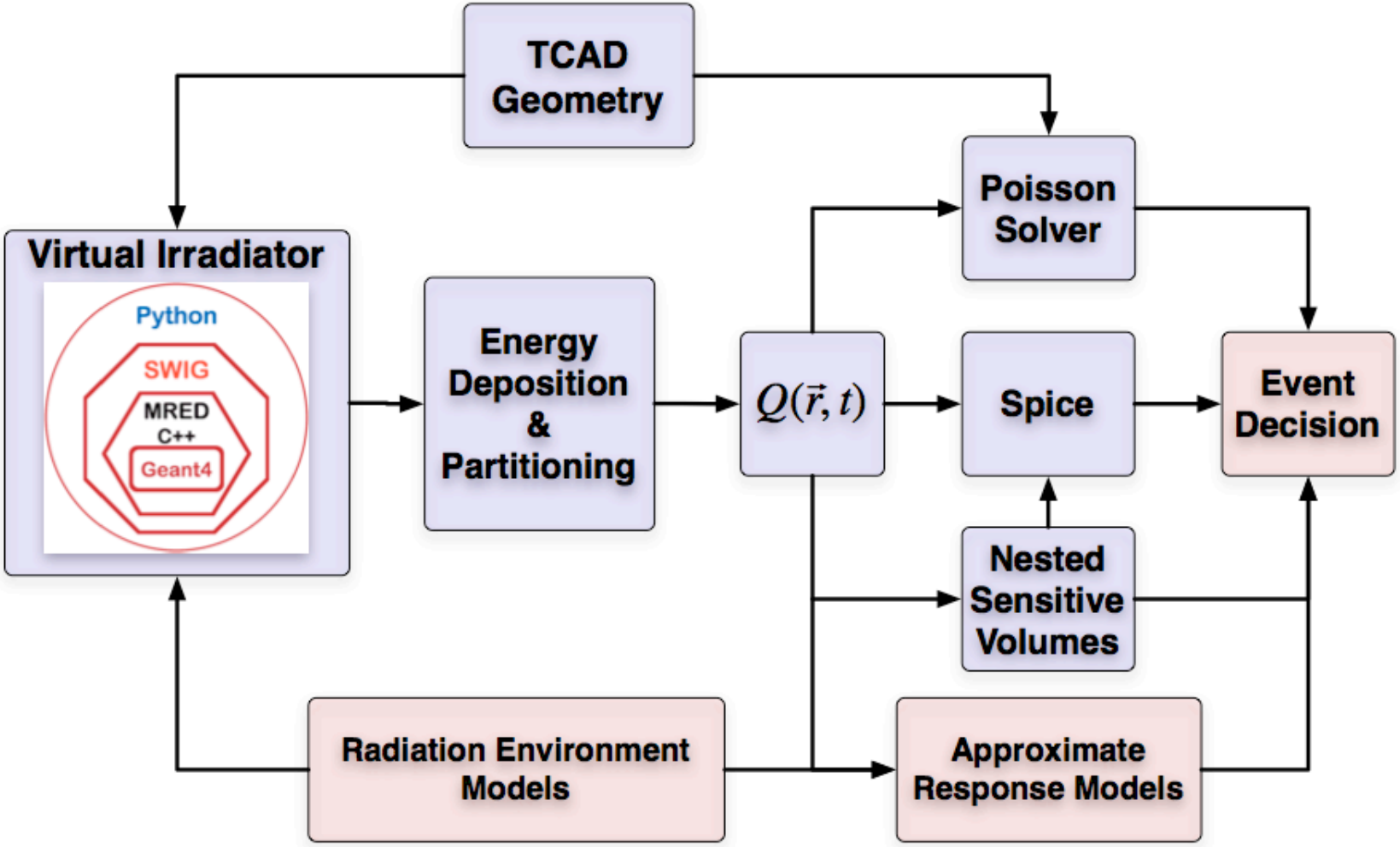


Physics of Radiation Interaction

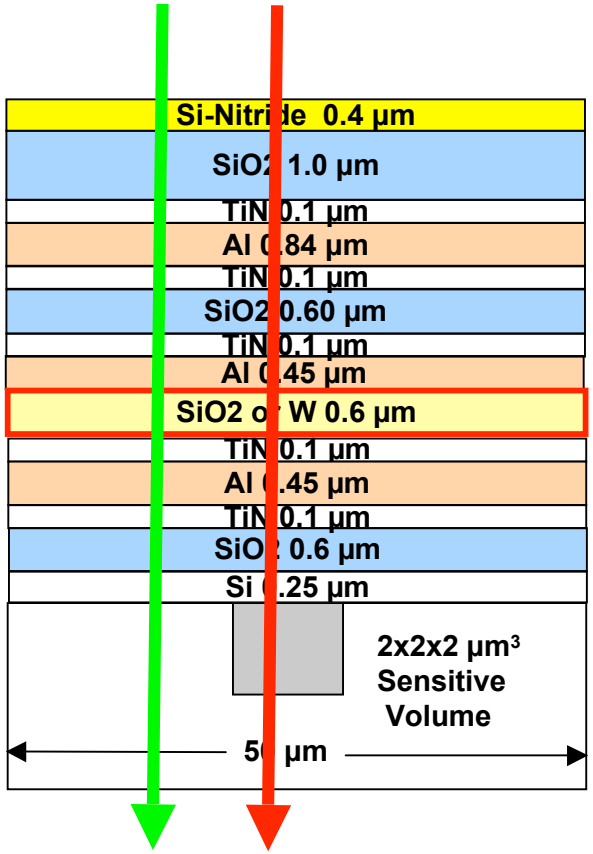
Progression of SEU Analysis

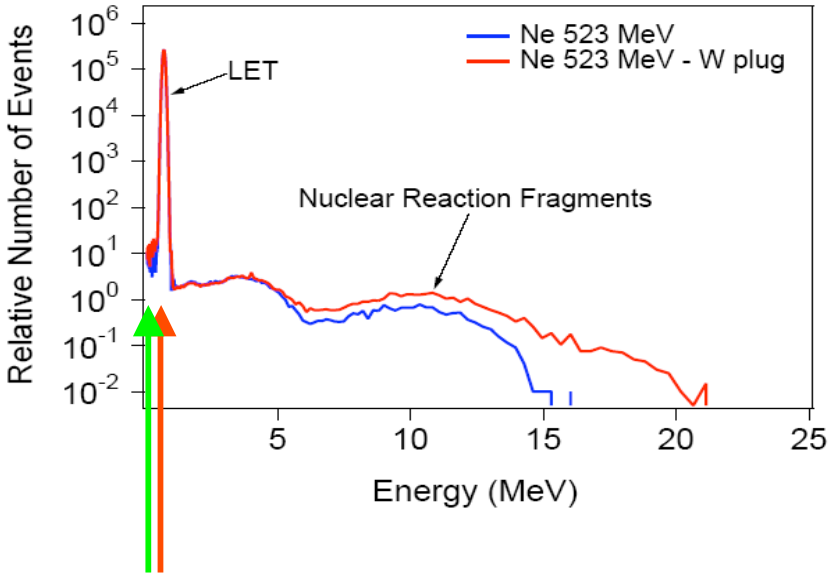
	CREME96	VU Then…	VU Research
Device/Circuit/System Virtualization			
Radiation Event Generation			
Response Prediction	Integral over path length Distribution + critical charge	 Multi-volume Calorimetry + Charge-collection models + Critical charge	Calorimetry TCAD or SPICE in the loop coincidence analysis

MRED Analysis Modalities



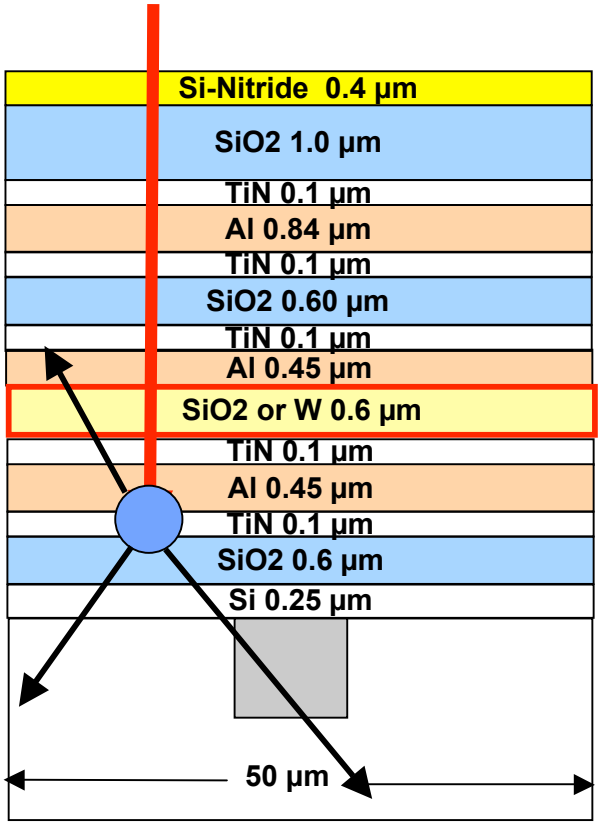
Calorimetry for SEU Predication

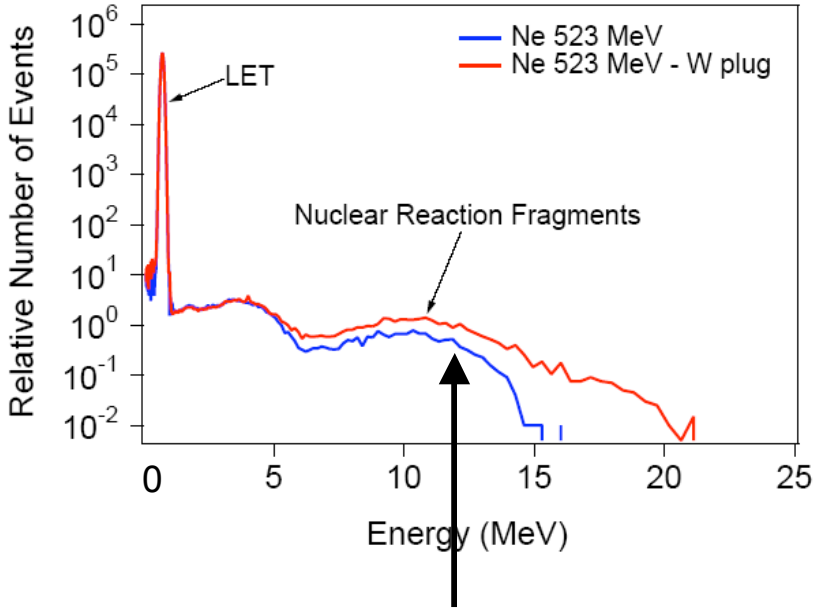




LET Contribution

Calorimetry for SEU Predication

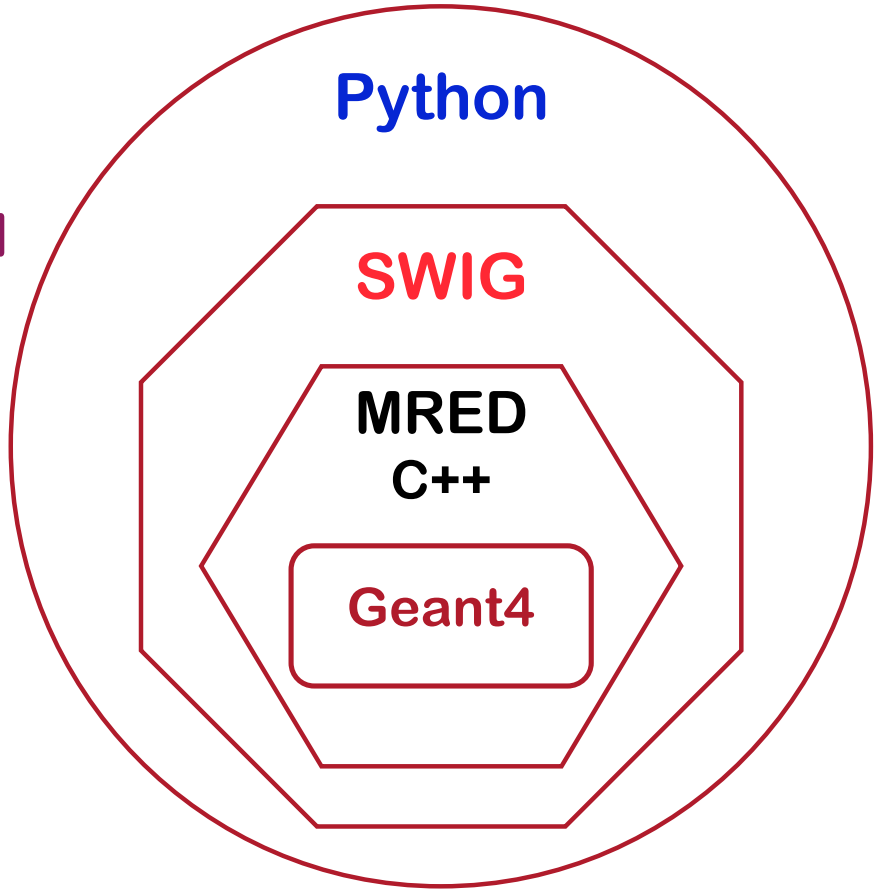




Nuclear Reactions

Structure of MRED

- Python: The common system language
- MRED: A Python module called mredPy
- Target: A 1500 node Linux cluster.
- Python writes submission scripts, controls job execution, and merges results.

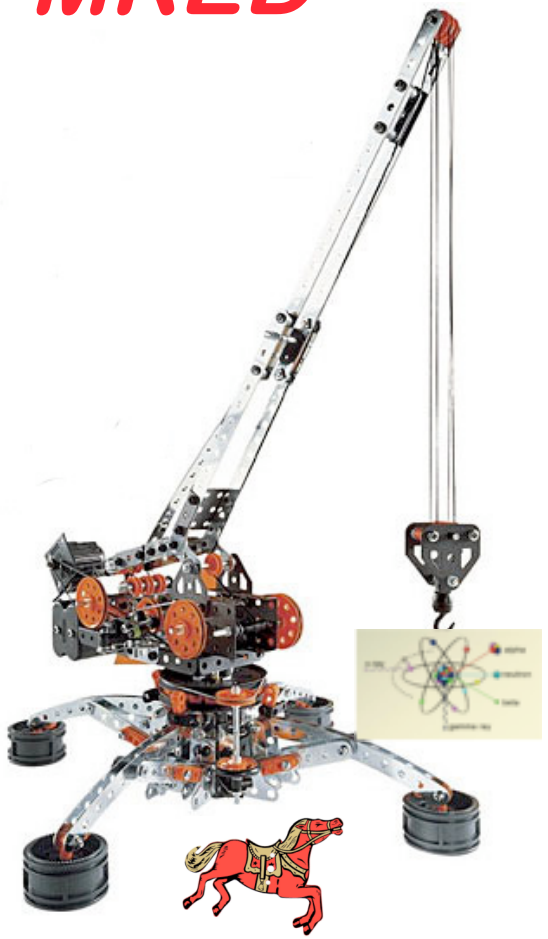


Geant4 is not a program!

Geant4

Source: http://www.acghs.org

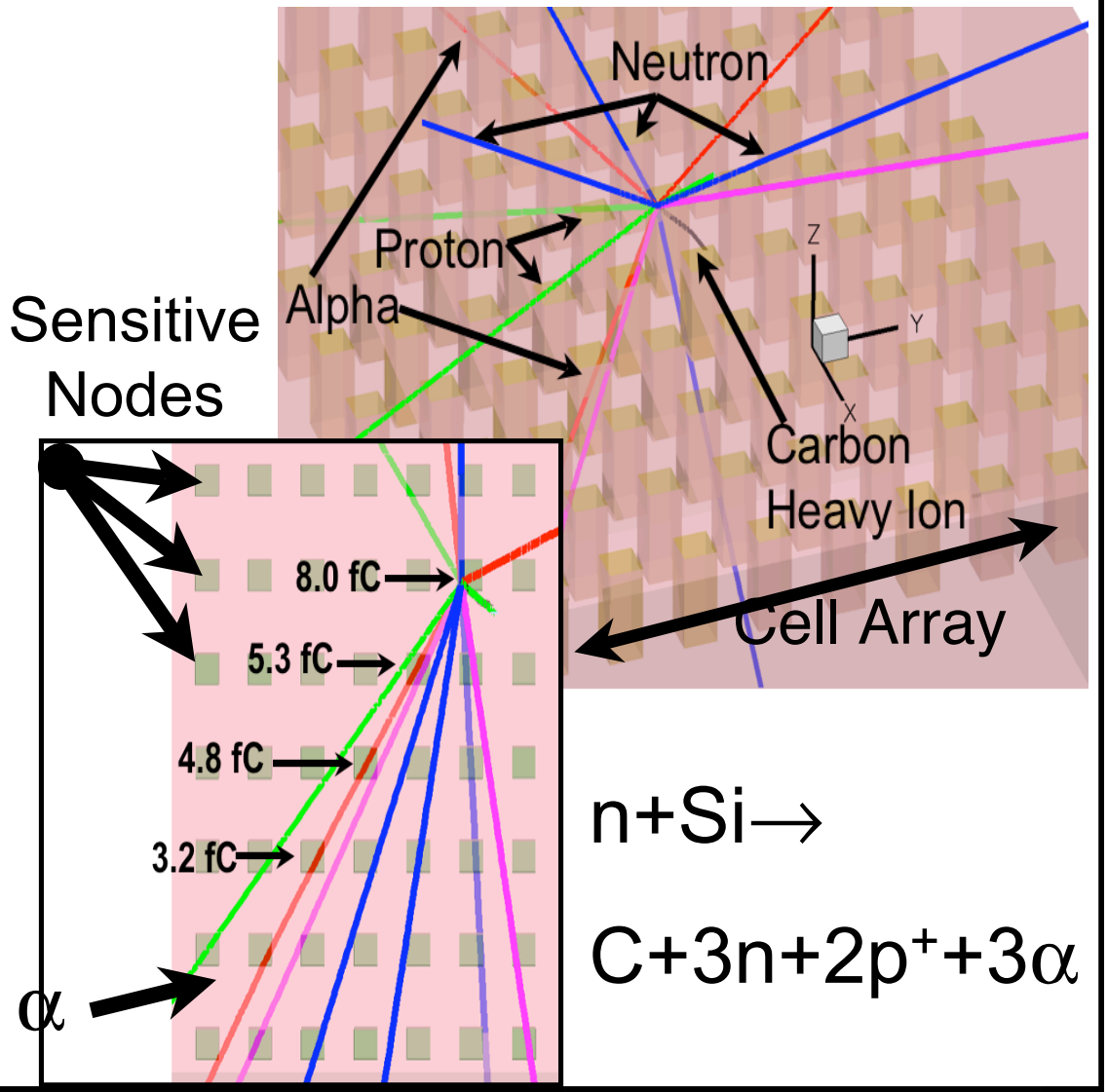
MRED



Source: http://www.fatbraintoys.com

Multiple Bit Upsets

- MRED tracks energy deposited in all layers
- Energy at each sensitive node is calculated

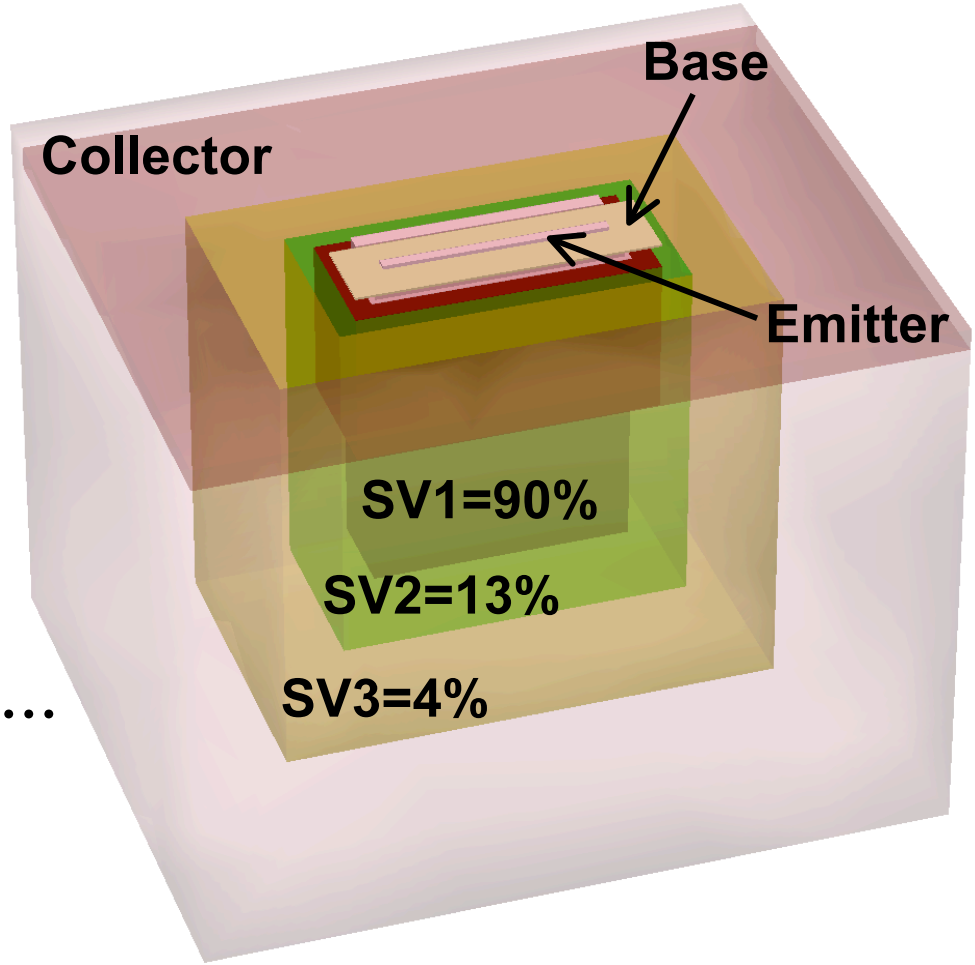


Nested Sensitive Volumes

- Weighted sensitive volumes
- General charge collection model
- Calibrated with measured data

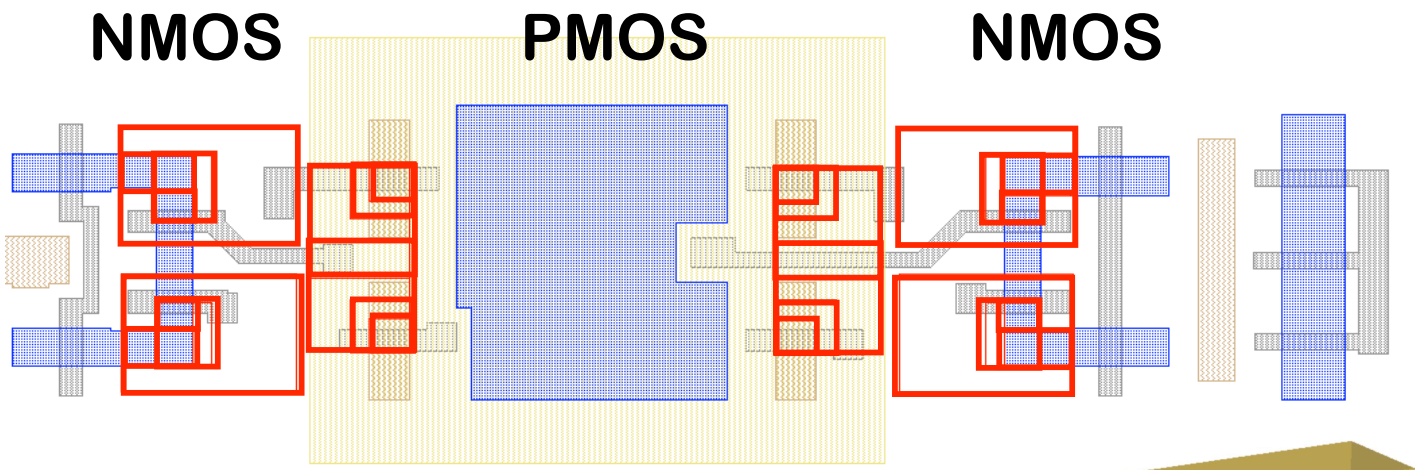
$$Q = \sum_{i=1}^{N} a_i E_i + \sum_{i,j=1}^{N} b_{ij} E_i E_j + \ldots$$

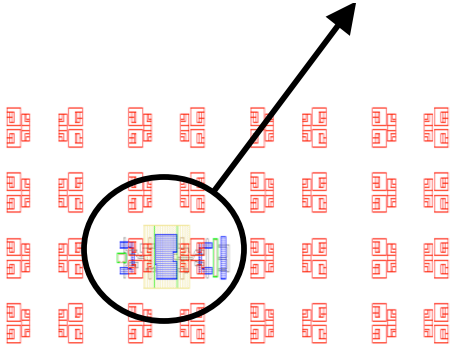
$$E_i = Sensitive\ Volume\ Energies$$



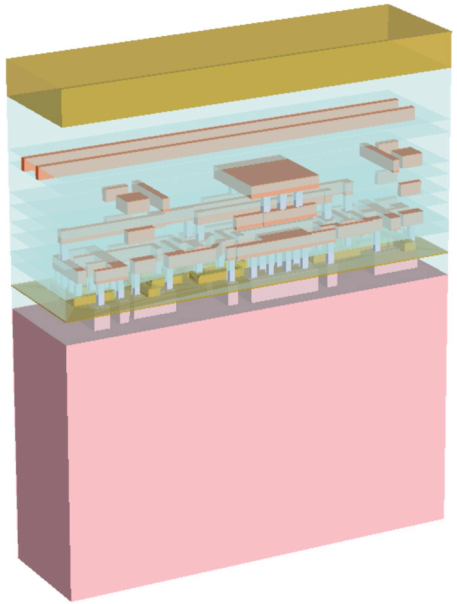
Multiple Sensitive Volumes

Nested Sensitive Volumes





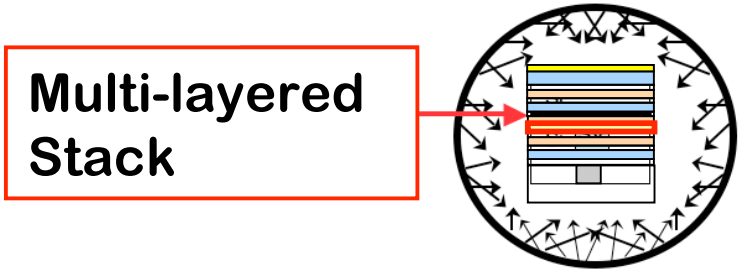
12-T DICE Latch

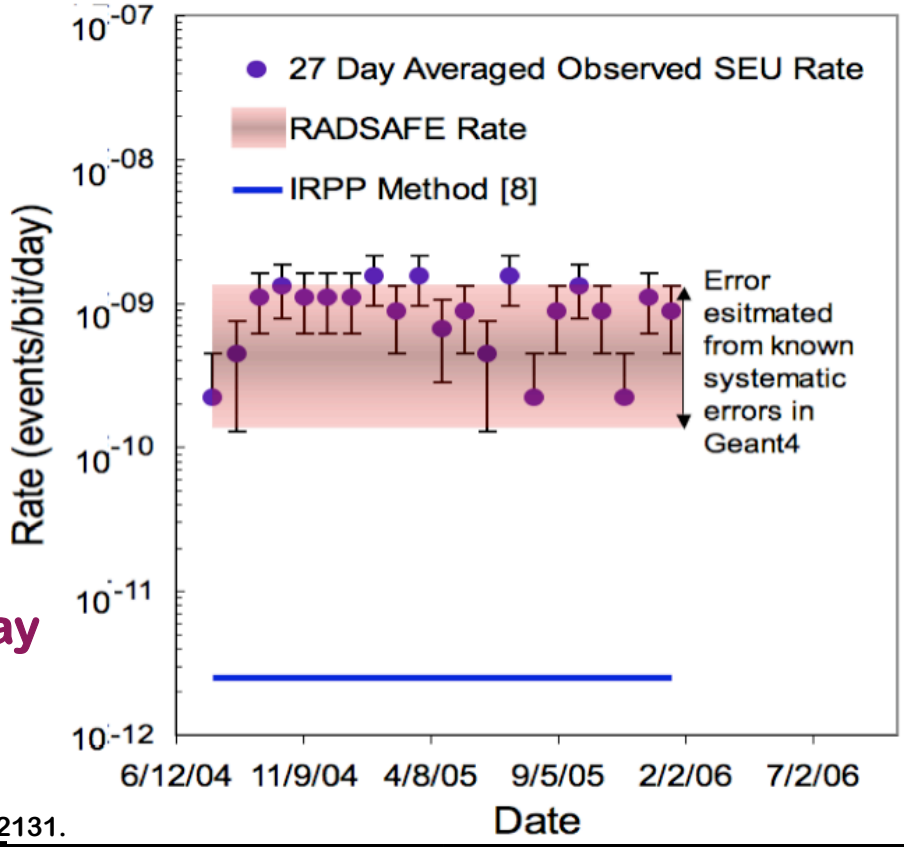


Kevin Warren, VU ISDE

SEU Rate for a Modern SRAM

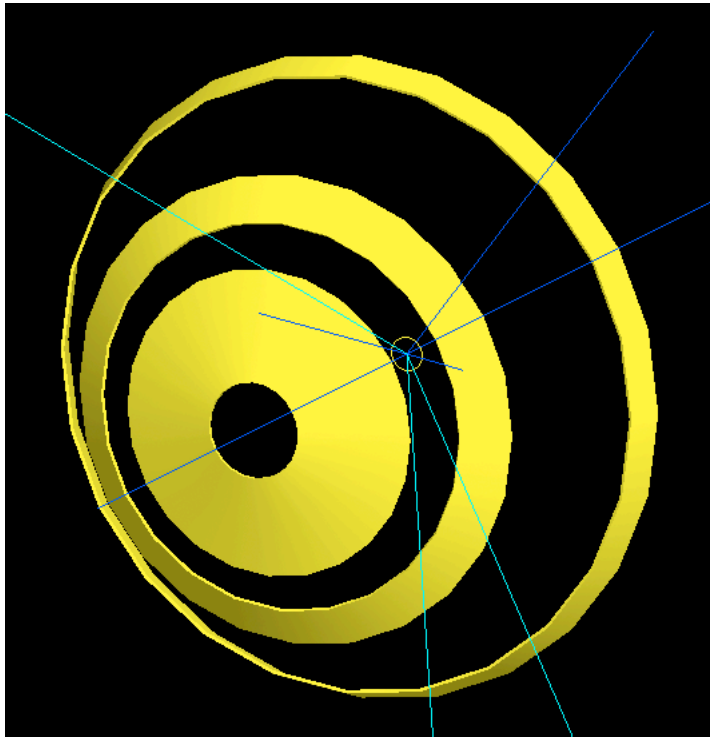
- Comparing a calculation with data from a real SRAM flown by NASA
- Observed Average SEU Rate:
  - $1x10^{-9}$ Events/Bit/Day
- Vendor predicted rate using CREME96:
  - $2x10^{-12}$ Events/Bit/Day
  - Classical Method nearly a factor 500 lower than the observed rate
- VU-ISDE rate:
  - All relevant physics with Geant4
  - $1.3x10^{-10}$ to $1.3x10^{-9}$ Errors/Bit/Day
  - Wide error bar from Geant4 ion-ion physics uncertainty

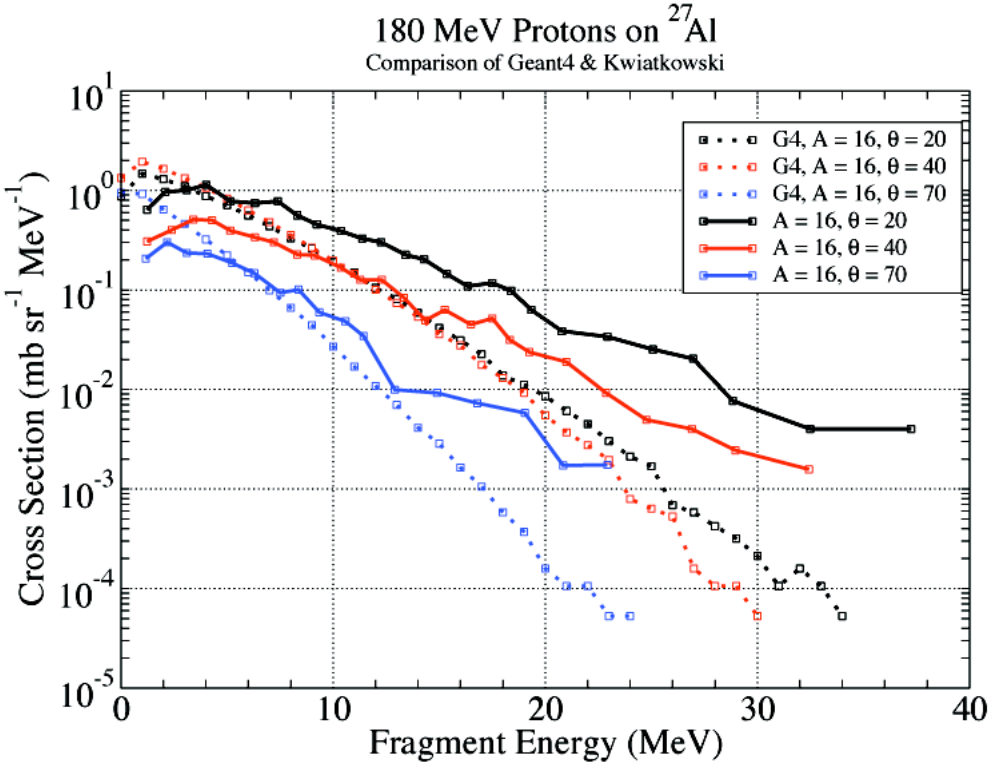




K. M. Warren, et al., IEEE Trans. Nucl. Sci. 52, 2005, pp. 2125-2131.

Validation: Nuclear Physics Literature





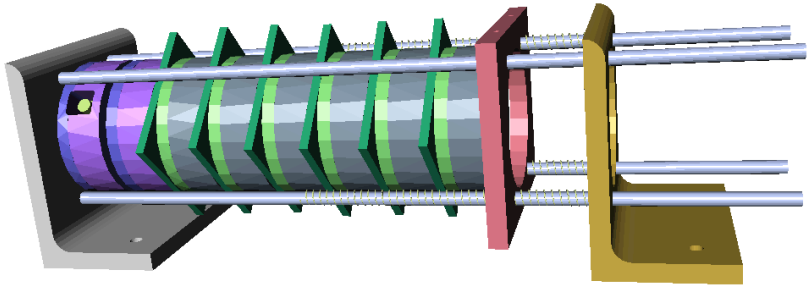
Notable Events

- Shift to mredPy is complete.
- MRED 8 Frozen; MRED 9 in development.
- VU Screened Scattering scheduled for December Geant4 release.
- Refined the plug-in mechanism for charge computation.
- Adapted SLAC JQMD interface for MRED
- Demonstration Integration of Spice with MRED.
- Mechanism for tagging non-ionizing energy added in Geant4.
- Geant4 parallel worlds matures.
- CREME-MC web site goes alpha.

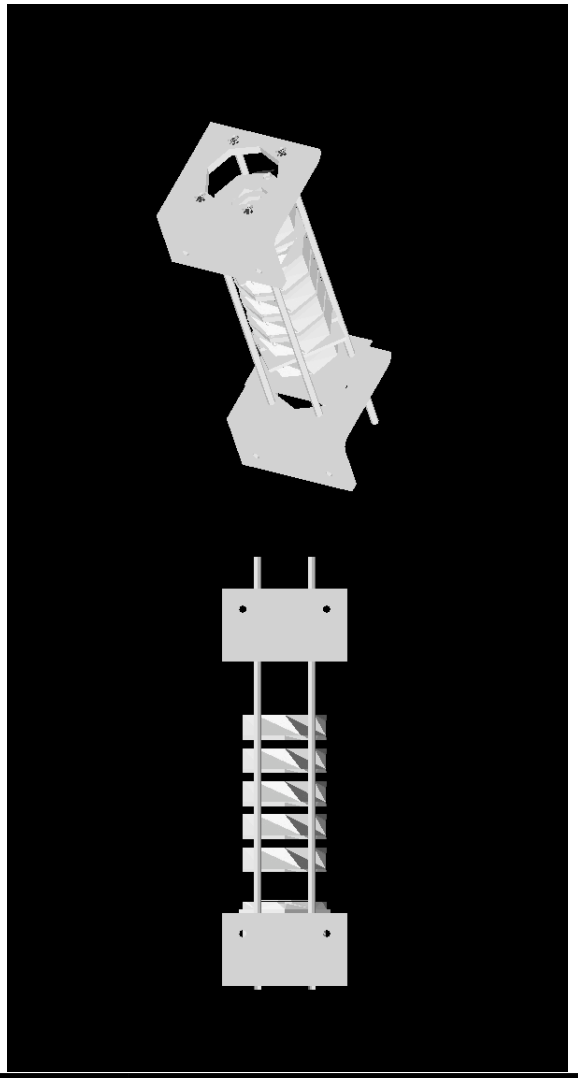
MRED 9

- Completely revised geometry system. Why?
  - GDML
  - DICOM
  - RLL Voxel arrays (MHM)
  - Worlds with mixed objects
  - Direct Python geometry construction
  - Enhanced replication and reflection objects
  - Other? E.g. STEP + GDML?
- Parallel-world detector space
- G4 messengers eliminated
- Improved generic analysis interface (TCAD, SPICE)
- TCAD without tetrahedra. FLOODS, SYNOPSIS

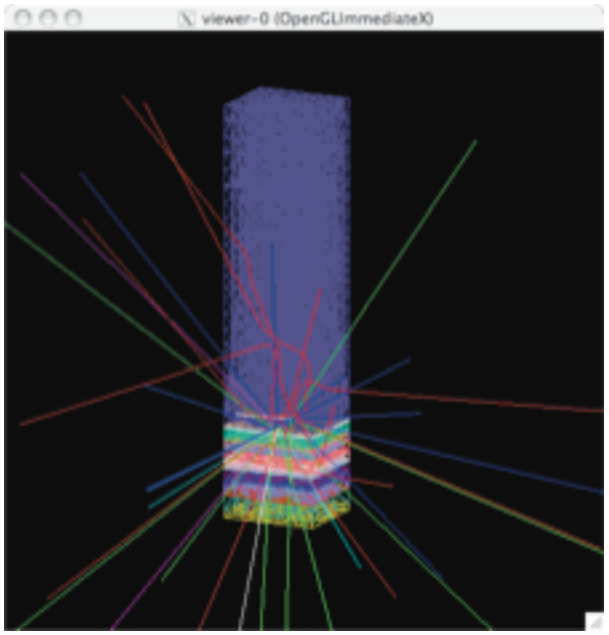
GDML Input



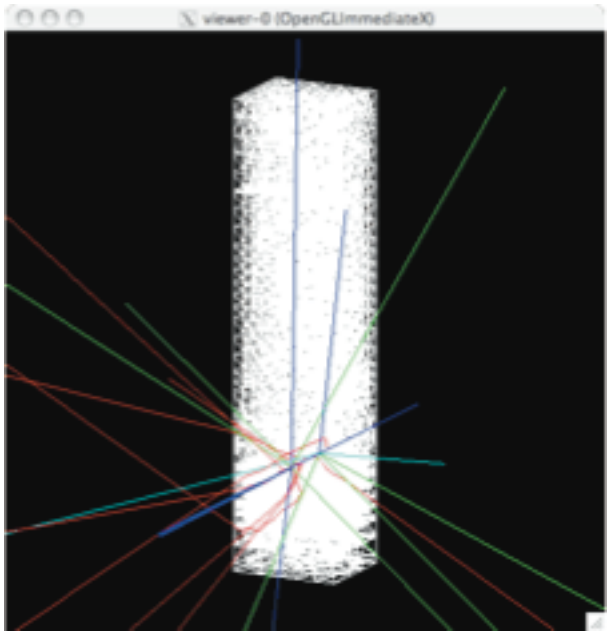
MSFC Spectrometer



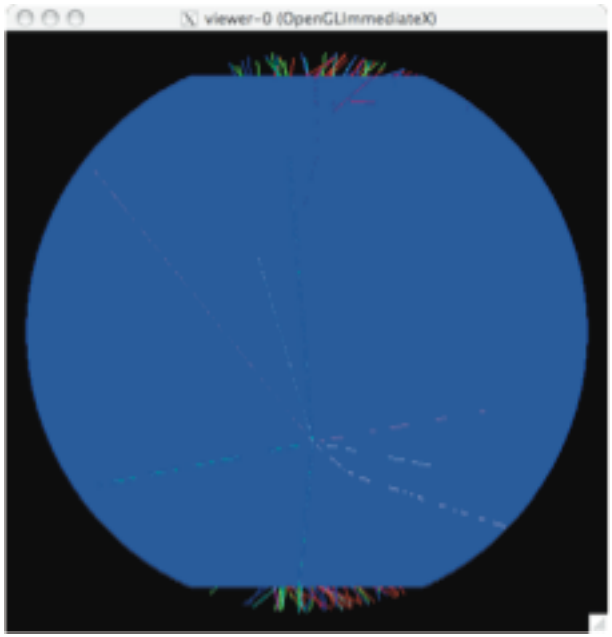
TCAD ⇒ GDML ⇒ 100k Events



fet_msh.grd
1k Events



fet_msh.gdml
1k Events



fet_msh.gdml
100k Events
Random
No errors!

More MRED 9

- Edep ionizing, non-ionizing in G4ScreenedScattering by June 2008.
- Mathematica mostly eliminated.
- Physics lists updated. Simplified nucleons - with & without HP n.
- Multi-dimensional (AIDA) histograms
- Enhanced visualization. DX interface?
- Possible sensitive volume changes. Replication? Hierarchy?
- Aggressive validation of ion-ion physics. G4 cascades, JQMD, G4QMD, PHITS. Other?
- Review E&M processes for space-electronics issues

Scope of Applications

- Full MRED on-orbit predictions of SEU rate
  - 0.25 μm CMOS RADHARD SRAM
  - IBM SiGe HBT Flip Flop
  - Xilinx FPGA-based SIRF DICE (90 nm and 65 nm)
  - RHBD DICE Latch
  - And others …
- Single-event and multiple-bit upsets in 65 nm, 90 nm,130 nm CMOS SRAM
  - TI, IBM, Jazz
- Neutron-induced SEU in CMOS SRAM
- SETs in SiGe HBTs
- SEGR in MOS devices
- Transient effects in HgCdTe IR-FPAs
- Displacement damage in Si, III-V, HgCdTe, et al.
- TID dose enhancement effects

Summary

- MRED is now a working tool.
- Analyses include multiple pathways to SEU prediction.
- High-level integration is now a priority.
- MRED 9 development now underway.
- Expect more - and more complex - applications…